AD-A163 295 NAVY ACTIVITY-LEVEL ENERGY SYSTEMS PLANNING PROCEDURE (A-LESP) USERS MANUAL(U) DEPARTMENT OF THE NAVY WASHINGTON DC 1986 1/4

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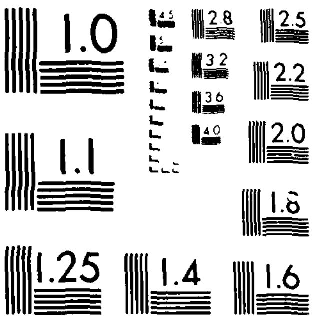
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GENERAL GUIDANCE

GENERAL GUIDANCE

PURPOSE

This manual is intended for use by Activity and Engineering Field Division (EFD) personnel in planning energy programs at the installation level. The step-by-step methodology presented in this manual, known as the Activity-Level Energy Systems Planning (A-LESP) procedure, represents the initial step in developing a rational, cost-effective energy program at the activity. By following the procedure, the user will be able to quickly review possible energy conservation opportunities (ECOs) and energy systems (ESs) and rank them according to savings to investment ratio (SIR). The installation's energy program will consist of the top-ranked ECOs and ESs.

RELATIONSHIP TO OTHER SURVEYS

The A-LESP procedure is an initial effort to identify the activity's promising energy options. As such, the procedure is designed as a 120-man-hour effort for a reasonably knowledgeable energy engineer at a moderate-sized installation. The procedure will be followed by the more intensive energy engineering survey supervised by the EFD. The EFD survey will examine all energy options in more depth, concentrating on areas of greatest opportunity as identified by the A-LESP procedure. The EFD will also perform specialty investigations related to boiler tuneups, air conditioning tuneups, industrial energy, energy monitoring and control systems, and alternate energy sources. Results of all energy survey efforts at an installation will be summarized within the Facility Energy Plan.

MANUAL ORGANIZATION

The A-LESP Users Manual is a dynamic tool for use by activity and EFD personnel. The manual is updated periodically with the issuance of change packages to user commands. Accordingly, the manual is the property of the command and not the individual; if the manual were to be removed from the command, it would miss future updates and would become obsolete.

Change packages will be issued by the Naval Civil Engineering Laboratory. After inserting the changes into the manual, the responsible individual will enter the appropriate information in the Record of Changes at the front of the manual.

The users manual is organized for easy use. The manual is tabbed for rapid section reference. Tabbed parts include:

- A-LESP Concepts. Description of economic concepts used in the analysis of energy options contained within the A-LESP manual.

- A-LESP Procedure. Detailed description of the A-LESP procedure including energy objectives, data collection, and analysis of ECOs and ESs.

- ECO Backup Sheets (gray tabs). Summary sheets providing descriptive information and technical data for each ECO. The ECOs are functionally grouped into six tabbed sections:

  - Building Envelope (BLDG ENV)
  - Distribution
  - Heating, Ventilation, and Air Conditioning (HVAC)
  - Hot Water
  - Lighting
  - Equipment

- ES Backup Sheets (blue tabs). Summary sheets providing descriptive information and technical data for each ES. The ESs are functionally grouped in three tabbed sections:

  - Cogeneration
  - Steam
  - Electric

- Supporting Information. Technical data for use with ECO and ES backup sheets:

  - Supporting Data
  - Glossary
  - Nomographs
  - Figures
  - Tables
  - Professional Contacts
  - Forms

BACKGROUND

As with most government and commercial organizations with extensive facilities, the Navy's interest in energy planning can be traced to the 1973-74 time frame, which was characterized by severe petroleum shortages and rapidly escalating energy prices. From the Navy and DOD perspectives, two concerns were paramount. First, the high cost of petroleum was forcing the Navy to divert funds from mission-related tasks to routine energy payments. Second, under threat of imposed shortages, prices were being controlled by foreign sources. National security

mandated that the Navy have continuous, uninterruptible fuel supplies for the fleet.

In this environment, it was essential for the Navy shore establishment to reduce its consumption of energy. This effort became a high-priority program within the Naval Facilities Engineering Command (NAVFAC). In short order, the EFDs began performing energy conservation surveys to reduce energy usage through operational changes and inexpensive retrofits. NAVFAC later provided central funding to facilitate the implementation of cost-effective retrofits with relatively high startup costs.

In addition to energy conservation surveys, the EFDs performed intensive investigations directed at certain aspects of energy usage with high payback potential. An early effort involved tuneup of activity boilers to increase efficiency and thereby reduce energy consumption. In recent years, efforts have been directed towards air conditioning tuneups and industrial energy conservation.

This proliferation of energy-related surveys and investigations has necessitated the development of the Facility Energy Plan (FEP). The FEP, which is written and updated by the EFD, summarizes identified ECOs and ESs at the activity and assesses the installation's progress in meeting established energy goals.

In 1980, DOD established quantitative goals for reducing the energy consumed by Naval shore facilities. A reduction in petroleum-based fuel consumption and a shift toward the use of coal and renewable energy sources were also mandated. These goals are shown in table G1. The energy and petroleum reduction goals are based on baseline consumption figures for FY75.

Table G1. DOD Energy Goals for Naval Shore Facilities

Energy Goal Category	DOD Energy Goal	FY85	FY90	FY95	FY2000
1	Percent reduction* in energy consumed per gross square foot**	20	25	30	35
2	Percent energy obtained from coal (including coal liquid and coal gas), solid waste, refuse derived fuel, and wood	10	15	20	35
3	Percent energy obtained from geothermal, solar, biomass, and other renewable sources	1	5	10	20
4	Percent reduction* in petroleum-based fuels consumption	30	35	40	45

*Relative to FY75.
**This does not apply to new construction.

Activity progress in achieving the energy reduction goals is tracked on a quarterly basis by the Naval Energy and Environmental Support Activity (NEESA). NEESA compiles data related to the types of fuels used and associated costs. NEESA's data serves as input into a DOD tracking system known as the Defense Energy Information System II (DEIS II). Both DEIS II and NEESA's Energy Audit Report are used by top-level management to assess installation progress in reducing energy usage.

The Naval Civil Engineering Laboratory (NCEL) is actively involved in research and development efforts related to energy. These efforts are presented in an annual NAVFAC publication entitled <u>Navy Shore Facilities Energy R&D Plan</u>. NCEL is engaged in all aspects of energy R&D, including facility retrofits, alternative energy systems, and integration of R&D results into a form suitable for activity use. This users manual represents the last category.

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A-LESP CONCEPTS

A-LESP CONCEPTS

EVALUATION

The A-LESP procedure is an evaluation procedure to rapidly identify and evaluate large numbers of energy conservation options. The energy options are defined in the Energy Conservation Opportunity (ECO) and Energy System (ES) sections of the manual. Evaluation of the energy options is accomplished in a three-step process. The first step is to identify representative facilities/systems at the activity. As each facility is identified, the feasibility of applicable energy options is evaluated, with feasible options listed for further consideration. The second and most important step is to establish the economic viability of the feasible options. This is accomplished by using a simplified version of the savings to investment ratio (SIR) in which the present worth of the savings in energy, operation, and maintenance is divided by the present worth of the cost of the project. A method for determining this ratio is included with each energy option. The third step is to establish energy goal categories and funding sources for economically viable energy options (SIR > 1).

BASIC ECONOMICS

Money has value over time as expressed by the price it commands. We recognize that one dollar today is not equivalent to one dollar at a future date. Therefore all dollar amounts in the SIR equations are based on "present value" (i.e., start of the project) for use in comparisons. This is done by adjusting life cycle savings and costs with present value factors.

Savings to Investment Ratio

SIR is a technique to determine whether an existing facility/system should be retrofitted or replaced with another facility/system on the basis of cost savings. An example of a facility retrofit is the insulation of a building's walls to effect energy savings. An example of a system replacement is the installation of a refuse-fired electric power plant to replace a conventional petroleum power plant with resulting savings in fuel costs and refuse disposal charges. It is cost-effective to implement a retrofit or a replacement if the expected lifetime savings exceed the initial investment required (SIR >1).

Present Value Factors

In order to make comparisons between SIRs they must first be on the same economic base. For our purposes, a facility/system life of 25 years will be used in all SIR analyses. During the analysis future periodic costs are adjusted (discounted) by means of present value factors. The factors differ if the payment is a one time cost (e.g., a car is purchased with cash), or spread out over the lifetime in cumulative uniform payments (e.g., a car is purchased in installments). After all adjustments have been made, SIR can then be evaluated.

The SIR equation can be expressed as:

$$SIR = \frac{\Delta E\ (\mathbf{DERF}) + \Delta O\&M\ (\mathbf{PYDF})}{C(\mathbf{PIF})}$$

where:

ΔE = Change in annual energy cost savings due to retrofit/replacement system
DERF = Differential Escalation Rate Factor
$\Delta O\&M$ = Change in annual O&M cost savings due to retrofit/replacement (negative value if higher O&M costs result)
PYDF = Project Year Discount Factor
C = Startup cost of retrofit/replacement system
PIF = Periodic Investment Factor

PYDF, **DERF**, and **PIF** are present value factors defined below.

PROJECT YEAR DISCOUNT FACTOR (PYDF)

Annual operation and maintenance costs increase with time at the same rate as the general economy. This rate is commonly known as the annual discount (or inflation) rate. Table A-1 shows the project year discount factor (PYDF) at several annual interest rates, cumulative uniform series (as defined in NAVFAC P-442). It is to be used when cash flows accrue in the same amount each year.

DIFFERENTIAL ESCALATION RATE FACTOR (DERF)

Energy costs, unlike O&M costs, increase or escalate at a rate greater than the annual discount rate (see table A-2). The "differential escalation rate" takes into account items whose prices are increasing at a rate faster than the general economy. DOD policy currently mandates the use of the following differential escalation rates:

Energy Source	Differential Escalation Rate
Coal	5%
Electricity	7%
Fuel Oil	8%
Natural Gas/LPG	8%

Since the rate of increase is greater, the present value factor for energy costs is correspondingly greater. Table A-2 shows the differential escalation rate factor (DERF) for different annual discount and escalation rates.

PERIODIC INVESTMENT FACTOR (PIF)

When the retrofit or replacement has a life of 25 years or more, the investment is just the startup cost, C. However, some energy options require periodic product replacement within the 25-year analysis period. These additional investment costs require use of the periodic investment factor (PIF). Table A-3 shows the PIF for 5-year increments of the stated 25-year lifetime using single amount series.

Table A-1. Project Year Discount Factor **(PYDF)** for Project Year 25

Annual Discount Rate* R(%)	Project Year Discount Factor (PYDF)
6	13.163
7	12.057
8	11.096
9	10.258
10	9.524

* Discount rate should be verified through NBS 135, <u>Life Cycle Costing Manual for the Federal Energy Management Programs</u>.

Table A-2. Differential Escalation Rate Factors **(DERF)** for Project Year 25

Annual Discount Rate R* (%)	Differential Escalation Rate D (%) (Fuels)					
	5	6	7	8	9	10
7	19.931	22.282	24.731	28.146	31.794	36.030
8	17.945	19.972	22.306	24.731	28.115	31.721
9	16.243	17.997	20.011	22.329	25.000	28.084
10	14.778	16.303	18.049	20.051	22.351	25.000

* Discount rates should be verified through NBS 135, <u>Life Cycle Costing Manual for the Federal Energy Management Programs</u>.

Note: This table is used for cost elements which are anticipated to escalate at a rate faster than general price levels.

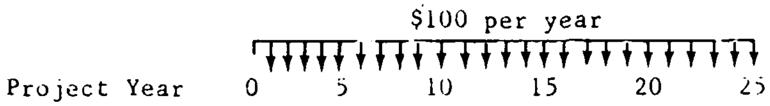
Table A-3. Periodic Investment Factor **(PIF)**

Replacement Year	Annual Discount Rate (R*) (%)				
	6	7	8	9	10
5	3.095	2.906	2.739	2.593	2.463
10	1.896	1.793	1.104	1.627	1.561
15	1.430	1.375	1.328	1.287	1.251
20	1.321	1.267	1.223	1.186	1.156
25	1.000	1.000	1.000	1.000	1.000

* Discount rates should be verified thorugh NBS 135, <u>Life Cycle Costing Manual for the Federal Energy Management Programs</u>.

EXAMPLE OF PYDF

A project is expected to have operation and maintenance costs of $100 per year for 25 years. What is the present value of the $100 payments at an annual discount rate of 10%?

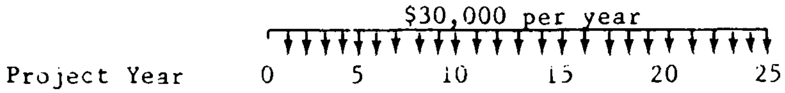


Looking at table A-1 for an annual discount rate of 10%, we see the value of PYDF is 9.524. Multiplying $100 times 9.524 (the cumulative amount of the twenty-five $100 payments) we see that the annual expediture of $100/yr for 25 years is equal to present expenditure (present worth) of $952.40.

EXAMPLE OF DERF

It is projected that the cost of oil will escalate 8% faster than the normal 10% annual discount rate. What is the present worth of these increased costs for 1,000 barrels of oil at $30.00 a barrel over a 25-year period?

Annual Cost = (No. barrels of Oil) x (Price/barrel)
= (1,000 barrels/year) x ($30.00/barrel)
= $30,000/year



- At normal 10% inflation:

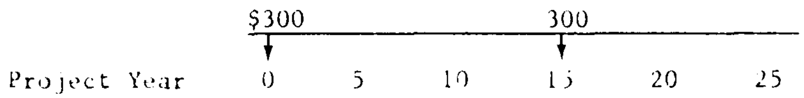
  Looking at table A-1, for 10% annual discount rate we see the value 9.524. Multiplying $30,000 times 9.524, we obtain the present value of the future payments, $285,720.

- At the 8% differential escalation rate for fuel oil:

  Looking at the 8% escalation rate column in table A-2 for an annual discount rate of 10%, we see the value 20.051. By multiplying $30,000 times 20.051 we obtain the present worth of the future payments, $601,500. The difference between the differential escalation rate and the annual discount factor reflects the increased cost of energy due to faster escalation rates.

EXAMPLE OF PIF

A project has a startup cost of $300.00, and has a lifetime of 15 years. For a 10% discount rate, what is the present value of the total investment required over the 25-year period?



From table A-3, the appropriate value of PIF is 1.251. Multiplying $300 by 1.251, we see the startup and replacement costs are equal to a present day (present worth) expenditure of $375.30.

PYDF DERIVATION

$$PYDF_n = \frac{e^{nr} - 1}{re^{nr}}$$

where:

n = the number of years of system/facility life (25)
e = 2.71828, the base of the natural logarithm
r = ln (1 + R)
R = the annual discount rate

DERF DERIVATION

$$DERF_n = \frac{e^{n(r-d)} - 1}{(r-d)\ e^{n(r-d)}}$$

where:

n = the number of years (25)
e = 2.71828, the base of the natural logarithm
r = ln (1 + R) (approximate to 8 decimal places)
R = the annual discount rate in decimal form
d = ln (1 + D) (approximate to 8 decimal places)
D = the annual differential escalation rate in decimal form

PIF DERIVATION

The periodic investment factor (PIF) was determined by first assuming that replacement cost equals startup cost and then summing individual PIF's over the equipment lifetime. A derivation of PIFs for 25, 20, 15, 10, and 5 year equipment lifetimes is provided below.

Given:

Net Present Value of Investment (NPV) = (1)

Startup cost (C) + (Replacement Cost (RC) x Present Value Factor (PVF_n))

Where: n = year equipment is replaced in

RC = C (2)

Then by substitution into equation 1:

$$NPV = C + C\ (PVF_n) \quad (3)$$
$$NPV = C\underbrace{(1 + PVF)}_{} \quad (4)$$

This is PIF

Then:

For a 25-year equipment life (not replaced during 25 year period, n = 25)

$$NPV = C(1 + PVF_{25}) \quad (5)$$

For a 20-year equipment life (replaced at year 20, n = 20)

$$NPV = C(1 + PVF_{20}) \quad (6)$$

For a 15-year equipment life (replaced at year 15, n = 15)

$$NPV = C(1 + PVF_{15}) \quad (7)$$

For a 10 year equipment life (replaced at years 10 and 20, n = 10, 20)

$$NPV = C(1 + PVF_{10} + PVF_{20}) \quad (8)$$

For a 5 year equipment life (replaced at years 5, 10, 15, and 20, n = 5, 10, 15, 20)

$$NPV = C(1 + PVF_5 + PVF_{10} + PVF_{15} + PVF_{20}) \quad (9)$$

From equations 4 through 9:

$$PIF_{25} = 1 + PVF_{25}$$
$$PIF_{20} = 1 + PVF_{20}$$
$$PIF_{15} = 1 + PVF_{15}$$
$$PIF_{10} = 1 + PVF_{10} + PVF_{20}$$
$$PIF_{5} = 1 + PVF_5 + PVF_{10} + PVF_{15} + PIF_{20}$$

The present value factor for "n" years (PVF_n) is determined by the following equation:

$$PVF_n = \frac{e^r-1}{re^{nr}}$$

Where n = project year that a replacement cost is incurred
e = 2.78128, the base of the natural logarithm
r = ln (1 + R)
R = the annual discount rate in decimal form

FURTHER ECONOMIC CONCEPTS

The preceding example calculations illustrate the use of the basic economic tables used in cost analysis for this manual. For further information the reader should consult NBS Handbook 135, Life Cycle Costing Manual for the Federal Energy Management Programs, dated December 1980, available through: Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

ENERGY COST

In calculating the savings to investment ratio for energy conservation opportunities (ECOs) and energy systems (ESs) table A-4 fuel prices were used:

Table A-4. Fuel Prices

Direct Energy Sources

Oil

No. 2: $\frac{\$30.00^{*}}{\text{barrel}} \times \frac{1 \text{ barrel}}{42 \text{ gallons}} \times \frac{1 \text{ gallon}}{139{,}600 \text{ Btu}^{**}} \times \frac{(10^{6}) \text{ Btu}}{\text{MBtu}} = \$5.12/\text{MBtu}$

No. 5: $\frac{\$28.00^{*}}{\text{barrel}} \times \frac{1 \text{ barrel}}{42 \text{ gallons}} \times \frac{1 \text{ gallon}}{145{,}100 \text{ MBtu}^{**}} \times \frac{(10^{6}) \text{ Btu}}{\text{MBtu}} = \$4.59/\text{MBtu}$

No. 6: $\frac{\$26.50^{*}}{\text{barrel}} \times \frac{1 \text{ barrel}}{42 \text{ gallons}} \times \frac{1 \text{ gallon}}{152{,}400 \text{ Btu}^{**}} \times \frac{(10^{6}) \text{ Btu}}{\text{MBtu}} = \$4.14/\text{MBtu}$

Natural Gas

$$\frac{\$0.60^{*}}{\text{therm}} \times \frac{1 \text{ therm}}{10^{5}\text{Btu}} \times \frac{10^{6} \text{ Btu}}{\text{MBtu}} = \$6.00/\text{MBtu}$$

Coal

$$\frac{\$43.94^{*}}{\text{short ton}} \times \frac{1 \text{ short ton}}{23.1 \times 10^{6} \text{ Btu}^{**}} \times \frac{10^{6} \text{ Btu}}{\text{MBtu}} = \$1.90/\text{MBtu}$$

Indirect Energy Sources

Electricity

$0.08/kwh used in computing energy cost in dollars

* Energy Users News, March 1983

**DOE A&E Guide

Electricity is listed as an indirect energy source. This results from the fact that electricity is normally generated using one of the primary fuels (direct energy sources). The thermal equivalent of 1 kilowatt hour is 3,413 Btu. In computing National Energy Savings (NES), however, the Navy has adopted a conversion factor of 11,600 Btu/kwh. This is simply 3,413 divided by an efficiency of 30%. This 30% is the average percentage of the energy value of the fuel (burned to generate electricity) that is available to the user after fuel combustion losses, mechanical to electrical conversion losses, and electrical distribution system losses have been accounted for.

EXAMPLE

Installing insulation in Building 1 will save 6,000 Btu/hr in air conditioning energy savings. If the air conditioner has an energy efficiency ratio (EER) of 6.8 Btu/watt-hr, how much money and energy will be saved in one year if the energy is generated outside the activity? If the energy is generated within the activity using No. 2 oil? (see figure A-1). Assume 3,000 annual operating hours.

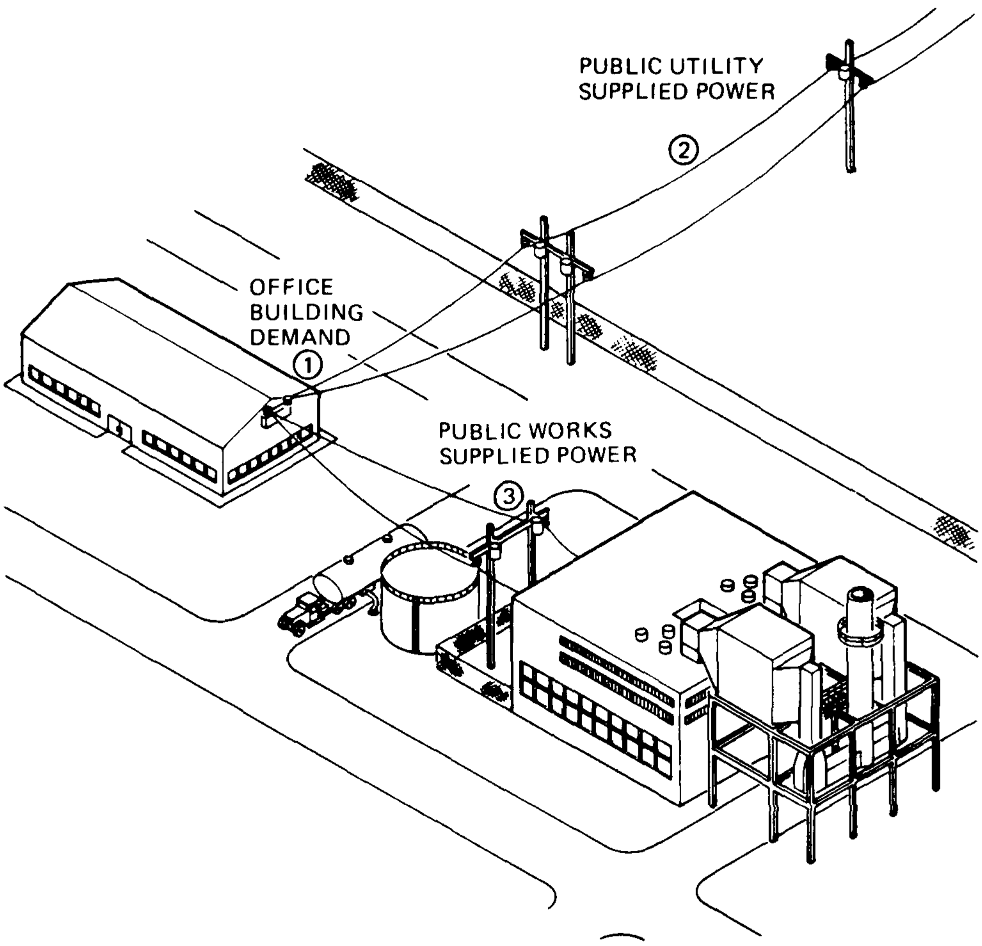


Figure A-1. Cost and Energy Savings Sources

(1) Energy Savings (air conditioning) = $6{,}000 \text{ Btu/hr} \times \frac{\text{watt}}{6.8 \text{ Btu/hr}} \times \frac{\text{kw}}{1{,}000 \text{ watt}} \times \frac{3{,}000 \text{ hr}}{\text{yr}} = 2{,}647 \text{ kwh/yr}$

<u>Energy generated outside the activity (see figure A-1)</u>:

(2) Cost Savings = $2{,}647 \text{ kwh/yr} \times \frac{\$0.08}{\text{kwh}} = \$212.00\text{/yr}$

<u>Energy generated within the activity</u> (see figure A-1):

(3) Energy Savings (NES) = $2{,}647 \text{ kwh/yr} \times \frac{11{,}600 \text{ Btu}}{\text{kwh}} \times \frac{\text{MBtu}}{10^6 \text{ Btu}} = 30.7 \text{ MBtu/yr}$

Cost Savings = $30.7 \text{ MBtu/yr} \times \frac{\$5.12}{\text{MBtu}} = \$157.00\text{/yr}$

FUNDING CATEGORIES

Funding constraints are a fact of life at Navy activities and deserve special mention here. Energy projects can be funded through normal channels, or they can qualify for fenced energy funding. The various funding options available to the installation are described below:

- Low-Cost or No-Cost Projects (Maintenance). These projects either require no funds or can be funded from available facility operation and maintenance funds. These projects should have top priority since their cost is either zero or very small.

- Activity Level Construction Projects. An activity commanding officer has authority to approve minor construction projects up to $25,000. As a general approach, the use of these funds should be investigated for projects having payback periods of 6 months or less.

- Activity Level Repair Projects. An activity commanding officer has authority to approve minor repair projects costing up to $75,000. As a general approach the use of these funds should be investigated for projects having pay back periods of 6 months or less.

- Major Claimant Level Projects. The responsible major claimant has authority to approve minor construction projects up to $200,000. The use of these funds should be considered for projects having payback periods of 18 months or less.

- Unspecified Minor Construction Projects (UMCP). Self-amortizing minor construction projects costing less than $500,000 can be approved under minor construction, provided that the construction will, within 3 years following completion of the project, result in savings in maintenance and operating costs in excess of the cost of the project. Funding levels are to be referred to CNO 2322407 Nov 1982.

- Repair Projects. Repair, as defined in chapter 4 of the Facilities Projects Manual (OPNAVINST 11010.20), is the restoration of a real property facility (under $200,000 for Energy Technology Applications Program (ETAP) or $75,000 for activity level repairs) to such condition that it may be effectively utilized for its designated purposes by overhaul, reprocessing, or replacement of constituent parts or materials that have deteriorated by action of the elements or usage and have not been corrected through maintenance. Thus, repair or repair by replacement funds can be used to bring a facility or a system up to current standards by using energy conservation measures, ranging from installation of insulation to installation of improved lighting. Funding levels are to be referred to CNO 2322407 Nov 1982.

- Energy Technology Applications Program (ETAP). ETAP applies operations and maintenance funds to rapid payback facility retrofit projects including major claimant special projects costing over $25,000 but less than the $200,000 minimum established for Energy Conservation Investment Program (ECIP). However, ETAP programs vary from major claimant to major claimant. Funding for special projects is part of the major claimant special project

program. Work performed under ETAP closely parallels the retrofit projects appropriate for ECIP, as described later. ETAP projects are generally for retrofit of existing facilities, but they may include some repair and maintenance if such work results in energy savings and can be amortized over the life of the projects. ETAP projects must be self-amortizing; a ratio of at least 20 MBtu for every $1,000 of project cost must be achieved.

- Energy Conservation Investment Program (ECIP). Military Construction (MILCON) funds are available through ECIP for cost-effective retrofits of existing facilities costing more than $200,000. Projects include retrofits to minimize energy loss, use of the latest energy-saving materials and equipment, and maximizing the efficiency of existing systems to ensure efficient operations. ECIP projects should have an SIR greater than one.

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PROCEDURE SECTION

PROCEDURE SECTION

A-LESP PROCEDURE

The A-LESP procedure is a step-by-step technique whereby the user (i.e., activity or EFD engineer) can identify promising ECOs and ESs for future investigation. The procedure is intended to be a 120-man-hour effort for a reasonably knowledgeable energy engineer at a moderate-sized activity. The procedure should be viewed as a "first cut" at analyzing the activity's energy situation to aid in the development of a viable energy program. Results of the A-LESP procedure can be used to guide more intensive energy investigations, supervised primarily by the EFD. The procedure consists of three steps:

Step 1. Establish representative facilities/systems and identify potentially feasible ECO/ES options for each facility/system.

Step 2. Calculate savings to investment ratios (SIRs) for potentially feasible energy options.

Step 3. Reorganize energy options by SIR and establish decision criteria for Navy energy and funding categories.

Once energy options have been identified, the energy officer along with the activity command will initiate more in-depth engineering studies and will finalize the activity energy program.

Step 1: Establish Representative Facilities/Systems and Identify Potentially Feasible ECO/ES Options for Each Facility/System.

The A-LESP Users Manual is specifically designed to identify cost-effective energy options with a minimum amount of time and data gathering. One technique used to accomplish this is to limit the number of facilities being examined by identifying representative facilities within the activity and then extrapolating for energy savings in similar facilities. It is important to limit the number of facilities in order to reduce manpower requirements, however, the facilities chosen must be representative of the activity as a whole. A list of typical facilities/systems is presented below.

Facility Types

1. Training
2. Maintenance
3. Medical
4. Administration Buildings
5. Dining Halls
6. Community
7. Housing
8. Industrial
9. Storage and Utility Buildings
10. Hangars
11. Special Applications/High Energy Use (e.g. Computer Center)

Utility Systems

1. Central Steam Plant (Steam or Hot Water)
2. Central Power Plant (Electrical)
3. Cogeneration Plant

As a facility is chosen, the energy officer enters it on Form I (see FORMS tab) along with any potentially feasible energy options contained within the A-LESP Users Manual. Potential feasibility is determined by looking at the feasibility requirement chart contained within each ECO option (gray tabs) and ES option (blue tabs). In order to shorten data collection time, representative buildings are analyzed at the activity. Results are then extrapolated for similar facility types. Four suggested extrapolation factors (F_1, F_2, F_3, F_4) can be used.

$F_1 = \frac{W_a}{W_b}$ where: W_b = Surface area of walls at representative building

W_a = Total surface area of walls for all similar activity buildings

$F_2 = \frac{R_a}{R_b}$ where: R_b = Surface area of roof at representative building

R_a = Total surface area of roofs at all similar activity buildings

$F_3 = \frac{V_a}{V_b}$ where: V_b = Volume of representative building

V_a = Total volume of all similar activity buildings

$F_4 = N$ N = Number of similar facilities/systems

The following list correlates ECOs with typical extrapolation factor:

ECO	EXTRAPOLATION FACTOR	ECO	EXTRAPOLATION FACTOR
BE 1	F_1, F_2	HVAC 11 - 17	F_3
BE 2	F_1	HVAC 18 - 23	Not Applicable
BE 3 - 6	F_1	HW 1 - 4	F_4
BE 7	F_2	L 1 - 6	F_4
BE 8 - 12	F_4	E 1 - 2	F_4
D 1	F_4		
D 2	F_4		
D 3	F_3		
HVAC 1 - 10	Not Applicable		

An example of a completed Form I is shown in figure PR-1. Once the facility and its associated ECO/ES options have been listed on Form I, the process is repeated for the next facility until all facilities/systems have been evaluated. In order

FORM I

REPRESENTATIVE FACILITIES AND
CORRESPONDING ENERGY OPTIONS

Representative Facility/System (i.e., Bldg No.)	Type of Facility (i.e., Hangar)	Possible ECOs (Section-Option)	Possible ESs (Section-Option)	Extrapolation Factor
Bldg 100	Administration	HVAC 12		10
Bldg 63	Storage and Utility	D 2		50
Bldg 63	Storage and Utility	HVAC 5		1
Bldg 10	Oil-fired Boiler		S 2	1
Bldg 10	Oil-fired Boiler		P 7	1
Bldg 21	Community	BE 2		5
Bldg 21	Community	BE 7		70
Bldg 341	Administration	BE 1		48

Figure PR-1. Sample Completed Form I Page ___ of ___

to verify that all pertinent facilities have been included during the identification process, it is recommended that buildings on an activity map be colored to identify with the representative facility/system, thereby eliminating the chance of overlooking an activity facility.

Step 2: Calculate SIRs for Potentially Feasible Energy Options.

Once Form I has been completed, the potentially feasible ECOs and ESs are transferred to Form II (FORMS tab) (figure PR-2). Form II is completed by using information and calculations provided in each ECO and ES sheet (gray/blue tabs). For each ECO/ES, perform the following tasks. First, collect information called for in "SURVEY DATA NEEDS." Second, perform the calculations called for in "PROCEDURE." Third, estimate costs using data in "GENERAL INFORMATION." Now, Form II can be completed, as follows:

The numbers in parenthesis below refer to the identical column in Form II.

Column (1) (NO.) is used as a reference designator for comparison between options.

Column (2) (ECO/ES OPTION) lists the name of the ECO/ES option under consideration as provided at the top of the ECO/ES sheet.

Column (3) (REPRESENTATIVE FACILITY) lists the facility building number.

Column (4) (NATIONAL ENERGY SAVINGS) is the total energy savings to the nation in Btus per year. Use the equation provided in the ECO/ES sheet.

Column (5) (LIFETIME OPERATION SAVINGS) is the numerator of the SIR equation provided in the ECO/ES sheet.

Column (6) (LIFETIME INVESTMENT) is the denominator of the SIR equation provided in the ECO/ES sheet.

Column (7) (EXTRAPOLATION FACTOR) is determined from either ECO/ES sheets or from facility information (see step 1 for further explanation of extrapolation factor).

Column (8) (TOTAL NATIONAL SAVINGS) is obtained by multiplying column 4 by column 7 (the extrapolation factor).

Column (9) (TOTAL INVESTMENT) is obtained by multiplying column 6 by column 7 (the extrapolation factor).

Column (10) (SAVINGS INVESTMENT RATIO) is obtained using the calculation given on each ECO/ES sheet.

Column (11) (FUNDING CATEGORY) is a column for listing various possible means of funding the energy options.

Column (12) (ENERGY GOAL CATEGORY) establishes which energy goal particular option will benefit from if the option is implemented (see table G1 under "GENERAL GUIDANCE" tab).

All steps necessary for each SIR are contained within the ECO/ES option sheets. The energy officer must follow the procedure given for the option and calculate the SIR. Each option sheet contains a description of the option, the required survey data needs, a step-by-step procedure for calculating the SIR, and a completed sample calculation. **Survey data** is obtained from either the manual's **Supporting Data sections** or from **site specific information.** The **accuracy** of site specific measurements used to compute SIR tends to have a linear effect on the SIRs accuracy; that is if the survey data is off by ±10% the SIR computed using that survey data will be off by ±10%. Since the A-LESP procedure is used for first cut estimating, the **accuracy required** for site specific survey data is ±10%. During the evaluation of the options, **calculation sheets should be identified and kept for future reference** should a question arise on assumptions or costs involved in a particular option.

Figure PR-3 shows Form III which provides a format for calculations performed for option sheet BE 7, INSTALL REFLECTIVE COATINGS ON ROOFS. Option BE 7 is contained in the Building Envelope Section (gray tab). Form III should be used for all option calculations and kept as a record for all options analyzed. Blank Form Is, IIs and IIIs are provided in the Forms Section.

Step 3: Reorganize Energy Options by SIR and Establish Decision Criteria for Navy Energy and Funding Categories.

As discussed in step 2, after Form I has been completed, the feasible ECO/ES options are transferred to Form II (FORMS tab) (figure PR-2) for calculation of energy option SIRs. After SIR calculations are completed, the ECO/ES option data is transferred to a clean Form II (figure PR-4), ranked in descending order of SIR. In addition the ECO/ES funding and energy goal categories (columns 11 and 12 respectively) are determined and entered on the new Form II (figure PR-4). Various funding programs should be reviewed prior to category assignment. The energy goal category refers to the specific reduction in energy based on the 1980 DOD Energy Goals for Naval Shore Facilities discussed in the General Guidance section, table G-1.

FORM II

PLANNING PROCEDURE SUMMARY - NAS TYPICAL INSTALLATION

1 NO.	2 ECO/ES OPTION	3 REPRE-SENTATIVE FACILITY	4 NATIONAL ENERGY SAVINGS (NES) (MBtu/yr)	5 LIFETIME OPERATION SAVINGS (S)($)	6 LIFETIME INVESTMENT (I)($)	7 EXTRAP FACTOR	8 TOTAL NATIONAL SAVINGS (MBtu/yr)	9 TOTAL INVESTMENT ($)	10 SAVINGS INVEST RATIO (SIR) (S/I)	11 FUNDING CATEGORY	12 ENERGY GOAL CATEGORY
1	Coal-Fired Central Heating Plant(S 2)	Bldg 10	62,000	53,232,140	5,200,000	1	62,000	5,200,000	10		
2	Wind Generated Elect(P 7)	Bldg 10	55,900	5,840,950	5,000,000	1	55,900	5,000,000	1.62		
3	Install Low Leakage Dampers (HVAC 12)	Bldg 100	11.3	1,164	938	10	113	9,380	1.24		
4	Replace Steam Traps(D 2)	Bldg 63	484	96,375	76	50	4,200	3,800	812		
5	Return Steam Condensate(HVAC 5)	Bldg 63	2,066	207,327	18,765	1	2,066	18,765	11.05		
6	Interior Part Insulation(BE 2)	Bldg 21	25.2	2,636	1,460	5	126	7,300	1.8		
7	Reflect Roof Coating(BE 7)	Bldg 21	180	19,754	10,927	70	12,600	764,890	1.81		
8	Install/Replace Insulation (BE 1)	Bldg 341	200	22,859	29,200	52	10,400	1,518,400	0.78		
						PAGE TOTAL					
						CUMULATIVE TOTAL					

Figure PR-2. Sample Completed Form II

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE		
Latitude	37°N	REP. FACILITY	Bldg. 21
Absorption coefficient (old)	0.8	ACT. FACILITIES	Bldg. 21-89,382,560
Absorption coefficient (new)	0.3	OPTION SHEET NO.	S-2
U-value of existing roof	0.14	A-LESP SURVEY DATE	5/83
Langleys	400	OPT. FEASIBILITY (YES/NO)	Yes
Dry bulb degree hours greater than 78°F	10,000	NES	180 MBtu/yr
		SIR	1.81
Cooling Energy Efficiency Ratio (EER)	6.8	FOLLOW-ON SURVEY DATE	8/83
		PROJECT SUBMITTAL DATE	1/84
Roof Size	100'x 200'	PROJECT COMPLETION DATE	5/84

Startup Cost (C): $\$0.35/ft^2$
Change in O&M: $\$0.01/ft^2$ ($200/yr increase)
Fuel saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%
Equipment Life: 10 years

CALCULATIONS	DATA VALUE USED
solar heat gain using old coating absorb. coef.	$10(10^3)$ Btu/ft^2
solar heat gain using new coating absorb. coef.	$4.8(10^3)$ Btu/ft^2

Roof Size = 100 x 200 ft (20,000 ft^2)

ELECTRICAL SAVINGS (kwh/yr) $= 10(10^3) - 4.8(10^3)\ \frac{\text{Btu}}{\text{ft}^2} \times \frac{1\text{wh}}{6.8\ \text{Btu}} \times \frac{1\text{kwh}}{1{,}000\ \text{wh}} = 0.77\text{kwh/ft}^2$

NES (MBtu/yr) $= (0.77\ \text{kwh/ft}^2\text{-yr}) \times ((11{,}600\ \text{Btu/kwh}) \times (\text{MBtu}/10^6\text{Btu}))$
$= 0.009\ \text{MBtu/ft}^2\text{-yr}$
$= 0.009\ \text{MBtu/ft}^2\text{-yr} \times 20{,}000\ \text{ft}^2 = 180\ \text{MBtu/yr}$

ELECTRICAL COST SAVINGS (\$/yr) $= 0.77\ \text{kwh/ft}^2 \times \$0.08/\text{kwh} = \$0.06/\text{ft}^2\text{-yr}$
$\$0.06/\text{ft}^2\text{-yr} \times 20{,}000\ \text{ft}^2 = \$1{,}200/\text{yr}$

$$\textbf{SIR} = \frac{\Delta E(\text{DERF}) - \Delta O\&M\ (\text{PYDF})}{C(\text{PIF})}$$

Δ**O&M** $= \$0.01/\text{ft}^2$

$$\textbf{SIR} = \frac{\$0.06/\text{ft}^2\ (18.049) - \$0.01/\text{ft}^2\ (9.524)}{\$0.35\ (1.561)} = 1.81$$

* See Building Envelope Section for entire Option Sheet.

Figure PR-3. Sample Calculations

FORM II

PLANNING PROCEDURE SUMMARY - NAS TYPICAL INSTALLATION

1 NO.	2 ECO/ES OPTION	3 REPRE-SENTATIVE FACILITY	4 NATIONAL ENERGY SAVINGS (NES) (MBtu/yr)	5 LIFETIME OPERATION SAVINGS (S)($)	6 LIFETIME INVESTMENT (I)($)	7 EXTRAP FACTOR	8 TOTAL NATIONAL SAVINGS (MBtu/yr)	9 TOTAL INVESTMENT ($)	10 SAVINGS INVEST RATIO (SIR) (S/I)	11 FUNDING CATEGORY	12 ENERGY GOAL CATEGORY
1	Replace Steam Traps(D 2)	Bldg 63	484	93,375	76	50	24,200	3,800	812	ALP	1,2
2	Return Steam Condensate(HVAC 5)	Bldg 63	2,066	207,327	18,765	1	2,066	18,765	11.05	ALP	1,2
3	Coal-Fired Central Heating Plant(S 2)	Bldg 10	62,000	53,232,140	5,200,000	1	52,000	5,200,000	10	ECIP	3
4	Reflect Roof Coating(BE 7)	Bldg 21	180	19,754	10,927	70	12,600	764,890	1.81	ECIP	1,4
5	Interior Part Insulation(BE 2)	Bldg 21	25.2	2,636	1,460	5	126	7,300	1.8	ALP	1,2
6	Wind Generated Elect(P 7)	Bldg 10	55,900	5,840,950	5,000,000	1	55,900	5,000,000	1.62	ECIP	4
7	Install Low Leakage Dampers (HVAC 12)	Bldg 100	11.3	1,164	938	10	113	9,380	1.24	ALP	1,2
8	Install/Replace Insulation (BE 1)	Bldg 341	200	22,859	29,200	52	10,400	1,518,400	0.78		
					PAGE TOTAL						
					CUMULATIVE TOTAL						

Figure PR-4. Sample New Form II, With Data Ranked in Descending Order of SIR and Funding and Energy Categories Entered

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BUILDING ENVELOPE

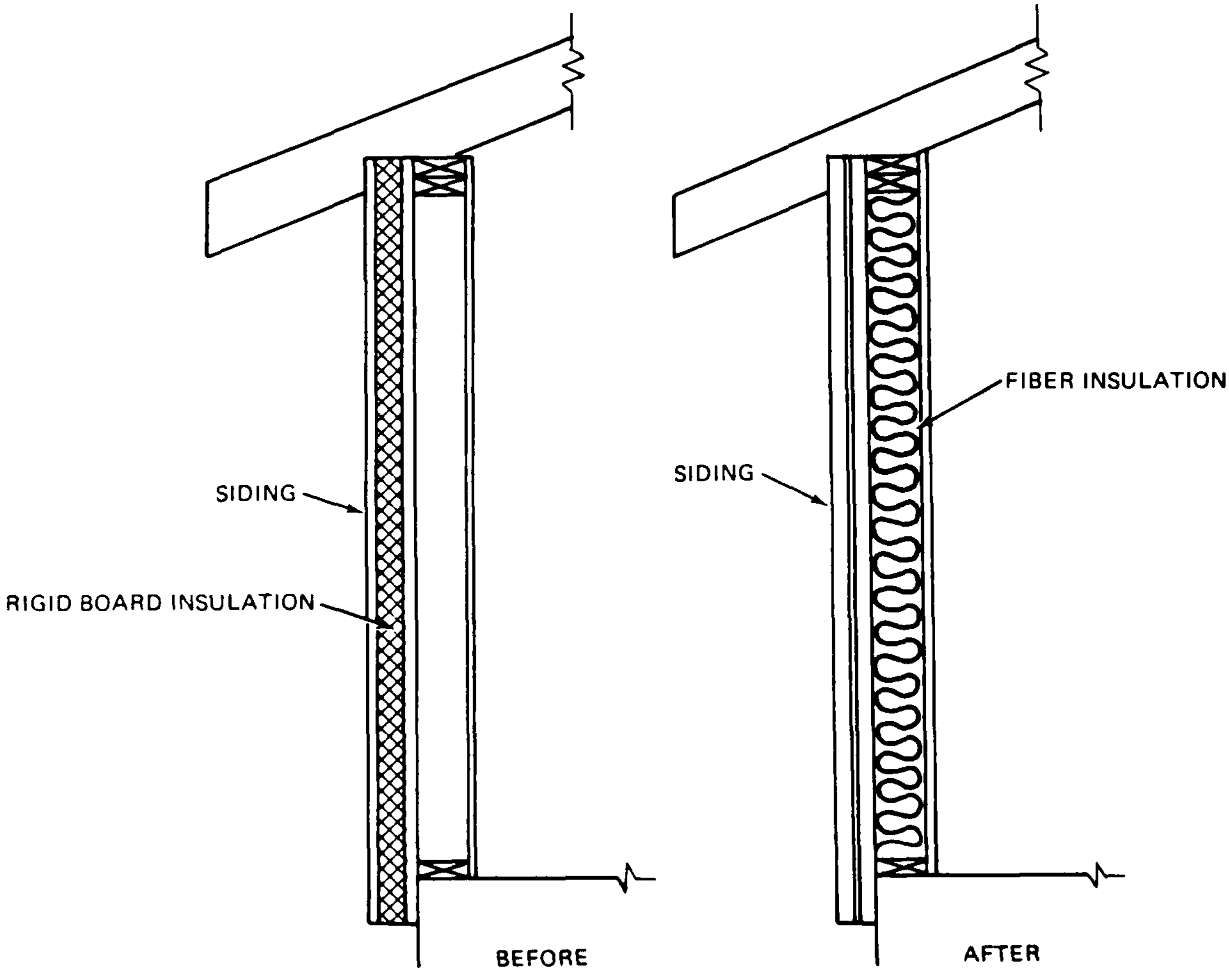


Figure BE-1. Install/Replace Insulation

BE 1. INSTALL/REPLACE INSULATION

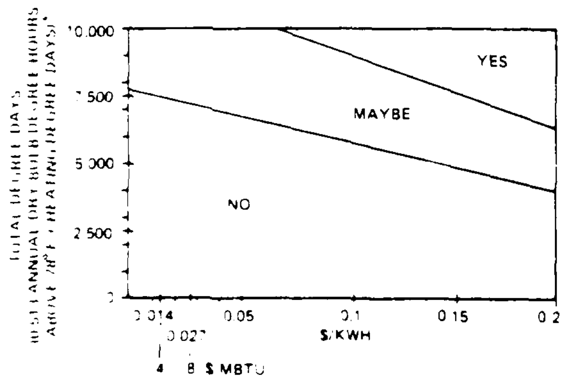
DESCRIPTION: The transmission of heat through a building's walls, roof, and floors can account for a significant portion of the total heating and cooling loads. Insulation is installed to reduce heat flow due to conduction. In many instances old buildings contain minimal or no insulation. Sometimes insulation becomes ineffective as a result of damage during construction or modification, deterioration due to weathering, or settling and compaction.

Wall areas can be insulated by adding insulation to the interior or exterior surfaces or wall cavities. Exterior and interior insulation must be protected from its environment. Treatment of door and window openings is addressed in subsequent energy conservation options. Equipment and fixtures may also have to be relocated. Insulation can be added to wall cavities by various methods. For example, if the walls have unobstructed internal voids, they can be insulated using blown-in granular insulation through small access holes that must be cut.

Roofs can be insulated in a variety of ways. If the space above the ceiling is not conditioned or used as a crawl space, the simplest procedure is to lay roll or batt insulation on top of the ceiling or blow in loose insulation. Insulation can also be installed directly under roof decks by suspending or attaching rigid board-type insulation or spraying the underside with foam insulation. When re-roofing, rigid board insulation can be added above the roof deck and covered with waterproofing. The insulation should be protected in high wear or traffic areas.

While floor slabs can be insulated at the perimeters, it is most effective to insulate suspended or framed floors above unheated spaces. Spray foams, rigid board, and roll-type insulations can be used. The latter should be well supported and protected from damage. Wire screening or plywood sheathing can be used.

FEASIBILITY REQUIREMENT:



*SEE MAPS 1 AND 3

BENEFITS/DETRIMENTS: Upgrading a building's insulation can save energy for heating and cooling. Depending on the types and procedures used, sound levels may be reduced and the building's fire rating improved.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- U-value of existing walls, roofs, floors	Tables 1 and 2
- Dimensions of walls, roofs, floors	Site Specific
- Heating degree days	Map 1, Supporting Data
- Langleys of solar radiation	Map 2, Supporting Data
- Exposure of walls (E,W,N,S)	Site Specific
- Absorption coefficients of walls and roofs	Table 5
- Latitude	Map 1, Supporting Data
- Occupied hours per week	Site Specific
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Use the appropriate nomographs 1 through 4 for the surface under consideration to determine the present annual heat losses for existing condition.

2. Repeat this procedure using the U-value of the new insulated surface. See table 1.

3. Fuel Savings (MBtu/yr) =

$$\frac{\text{Heat Loss (existing) - Heat Loss (insulated)}}{\text{Heating Plant Efficiency}}$$

4. Electrical Savings (kwh/yr) =

   Repeat steps 1 and 2 using nomographs 5-8 to determine the electrical savings (i.e. annual cooling energy saved in kwh/yr) as follows:

$$\text{Cooling Loss (existing) - Cooling Loss (insulated)} \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $\$1.46/\text{ft}^2$ (installed: labor and materials for polystrene insulation) for accessible roof, floors, and walls
Replacement Cost: Same as startup cost
Equipment Life: 25 years (depending on structure)
Skill Level of Personnel Required: Insulation contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions	
Area of insulation	20,000 ft^2
Latitude	37°N
Old U-value	0.203
New U-value	0.086
Absorption coefficient	0.8
Exposure direction	South
Langleys	400
Occupied hours/week	40
Heating degree days	4,000
Dry bulb degree hours above 78°F	7,000
Heating plant efficiency (HEFF)	0.75
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: None
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Energy Loss (fuel uninsul)	$8(10^3)$ Btu/ft^2	Nomo 2
Energy Loss (fuel insul)	$4(10^3)$ Btu/ft^2	Table 1 for U-value and Nomo 2
Energy Loss (electrical uninsul)	$5(10^3)$ Btu/ft^2	Nomo 6
Energy Loss (electrical insul)	$2.5(10^3)$ Btu/ft^2	Table 1 for U-value and Nomo 6

FUEL SAVINGS (MBtu/ft^2-yr) =

$$\frac{(8 \times 10^3) - (4 \times 10^3)}{0.75} = 5.3 \times 10^{-3} \text{ MBtu/ft}^2\text{-yr}$$

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$(5(10^3) - 2.5(10^3)) \times \frac{1}{6.8\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1,000\ wh} =$$

0.37 kwh/ft^2-yr

NES (MBtu/yr) =

5.3×10^{-3} MBtu/ft^2-yr + (0.37 kwh/ft^2-yr x

11,600 Btu/kwh x MBtu/10^6 Btu) = 0.01 MBtu/ft^2-yr

0.01 MBtu/ft^2-yr x 20,000 ft^2 = 200 MBtu/yr

FUEL COST SAVINGS ($/yr) =

5.3×10^{-3} (MBtu/ft^2-yr) x $5.12/MBtu = $0.03/$ft^2$-yr

$0.03/$ft^2$-yr x 20,000 ft^2 = $600/yr

ELECTRICITY COST SAVINGS ($/yr) =

0.37 kwh/ft^2-yr x $0.08/kwh = $0.03/$ft^2$-yr

$0.03/$ft^2$-yr x 20,000 ft^2 = $600/yr

SIR =

$$\frac{\$0.03/ft^2(20.05) + \$0.03/ft^2(18.049)}{\$1.46/ft^2\ (1)}$$

= 0.78

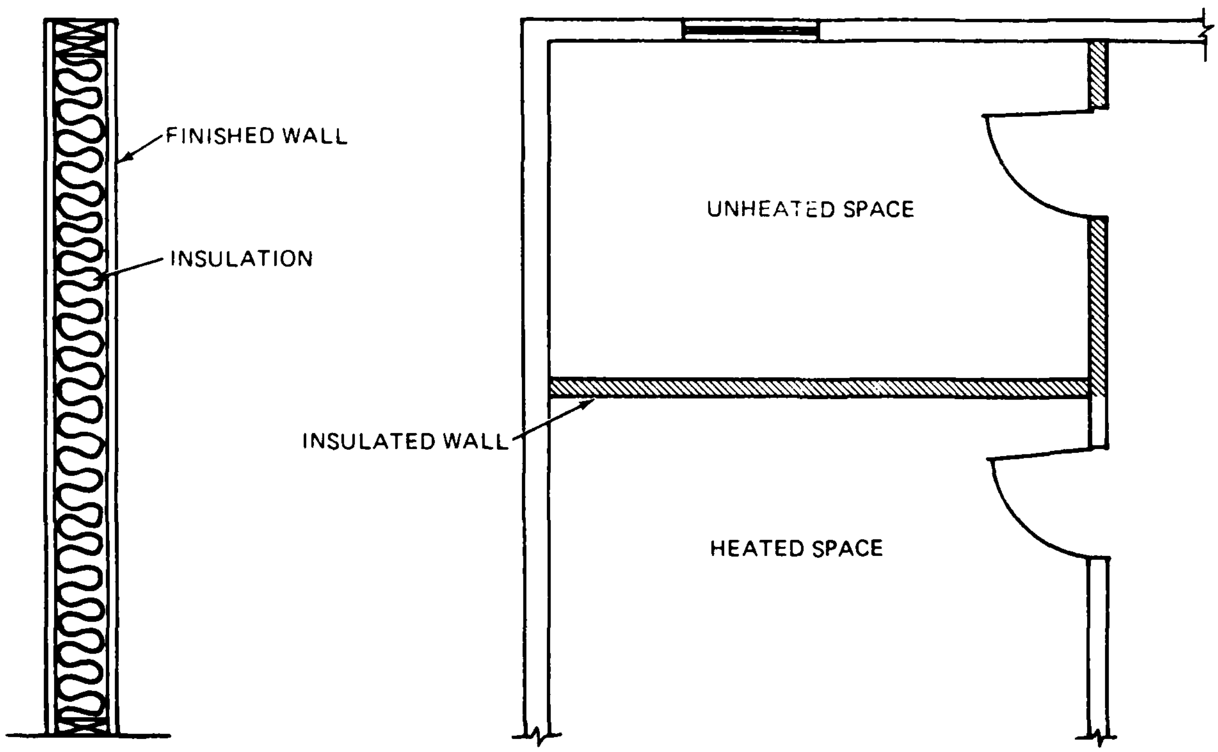
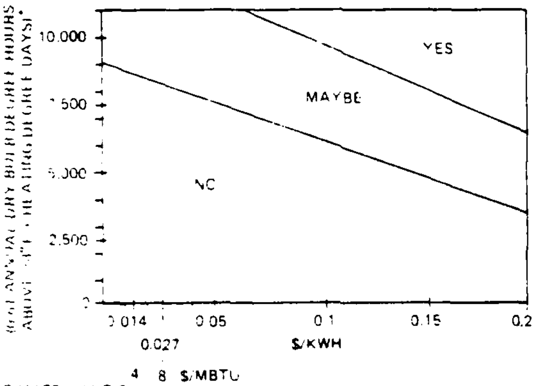


Figure BE-2. Insulate Between Conditioned and Nonconditioned Spaces

BE 2. INSULATE BETWEEN CONDITIONED AND NONCONDITIONED SPACES

DESCRIPTION: While a building's exterior surfaces may be insulated, internal partitions between spaces may not. Changes in building utilization may result in some areas being conditioned only occasionally, while adjoining spaces are fully conditioned. Installing insulation and reducing air infiltration between these zones can save a significant amount of energy. A vapor barrier to prevent the accumulation and condensation of water within the insulation should be installed at the conditioned space surface. Storage facilities requiring only humidity control should be separated from fully conditioned spaces.

FEASIBILITY REQUIREMENT:



*SEE MAPS 1 AND 3

BENEFITS DETRIMENTS: Energy used to maintain specific environmental conditions can be reduced by limiting the flow of energy to uncontrolled areas.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- U-value of existing interior partitions	Tables 1 and 2
- Building description loss factor	Table 10
- Heating degree days	Map 1, Supporting Data
- Volume of nonconditioned space	Site Specific
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Dimensions of partitions	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific
- Heating plant efficiency (HEFF)	Site Specific

PROCEDURE:

1. Determine U-value of insulation used in partition (see tables 1 and 2).

2. Calculate the cubic volume of the nonconditioned space. Select the loss factor (F) from table 10.

3. Calculate heating loss for insulated and uninsulated partitions. Use equation to determine energy loss for both heating and cooling season.

$$\text{Energy lost} = \frac{(Ap \times Up) \times (V \times F)}{(Ap \times Up) + (V \times F)} \times D$$

Ap = Area of Partition (ft²)
Up = U-Value of Partition (Btu/ft²-°F-hr)
V = Volume of Nonconditioned Space (ft³)
F = Loss Factor (Btu/ft³-°F-hr)
D = Degree Hours/Year
- for heating: heating degree days (map 1) x 24
- for cooling: cooling degree hours above 78°F (map 3)

4. Fuel Savings (Btu/yr) =

$$\frac{\text{Heat Lost (uninsul)} - \text{Heat Lost (insul)}}{\text{Heating Plant Efficiency}}$$

5. Electrical Savings (kwh/yr) =

$$\text{Cooling Lost (uninsul)} - \text{Cooling Lost (insul)} \times \frac{1}{EER\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1{,}000\ wh}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $1.46/ft² (installed: labor and materials for polystrene insulation) for accessible roofs and walls
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Insulation contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

Latitude	37°N
Old U-value	0.4
New U-value	0.1
Absorption coefficient	0.8
Exposure direction	South
Langleys	400
Heat loss factor (Btu/ft³-°F-hr)	0.08
Heating degree days	4,000
Dry bulb degree hours above 78°F	7,000
Heating plant efficiency (HEFF)	75%
Cooling energy efficiency ratio (EER)	6.8
Area of partition	1,000 ft²
Volume of nonconditioned space	10,000 ft³

Change in O&M: None
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\underset{\text{(fuel uninsul)}}{\text{Energy Lost}} = \frac{(1{,}000 \times 0.4) \times (10{,}000 \times 0.08) \times (4{,}000)(24)}{(1{,}000 \times 0.4) + (10{,}000 \times 0.08)}$$

$$\times\ (\text{MBtu}/10^6\ \text{Btu}) = 25.6\ \text{MBtu/yr}$$

Energy Lost (fuel insul) $= \frac{(1{,}000 \times 0.1) \times (10{,}000 \times 0.08) \times (4{,}000)(24)}{(1{,}000 \times 0.1) + (10{,}000 \times 0.08)} \times (\text{MBtu}/10^6\ \text{Btu})$

$= 8.5$ MBtu/yr

Energy Lost (electrical uninsul) $= \frac{(1{,}000 \times 0.4) \times (10{,}000 \times 0.08) \times 7{,}000}{(1{,}000 \times 0.4) + (10{,}000 \times 0.08)} \times (\text{MBtu}/10^6\ \text{Btu}$

$= 1.9$ MBtu/yr

Energy Lost (electrical insul) $= \frac{(1{,}000 \times 0.1) \times (10{,}000 \times 0.08) \times 7{,}000}{(1{,}000 \times 0.1) + (10{,}000 \times 0.08)} \times (\text{MBtu}/10^6\ \text{Btu})$

$= 0.62$ MBtu/yr

FUEL SAVINGS (MBtu/yr) =

$\frac{25.5(10^6) - 8.5(10^6)}{0.75} = 23$ MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

$1.9(10^6) - 0.62(10^6) \times \frac{1}{3.8\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}} = 190$ kwh/yr

NES (MBtu/yr) =

23 MBtu/yr + (190 kwh/yr x

11,600 Btu/kwh x (MBtu/10^6 Btu)) = 25.2 MBtu/yr

FUEL COST SAVINGS ($/yr) =

23 MBtu/yr x $5.12/MBtu = $117.8/yr

ELECTRICITY COST SAVINGS ($/yr) =

190 kwh/yr x $0.08/kwh = $15.20/yr

SIR =

$\frac{\$117.8\ (20.05) + \$15.20\ (18.049)}{\$1{,}460.00\ (1)}$

$= 1.8$

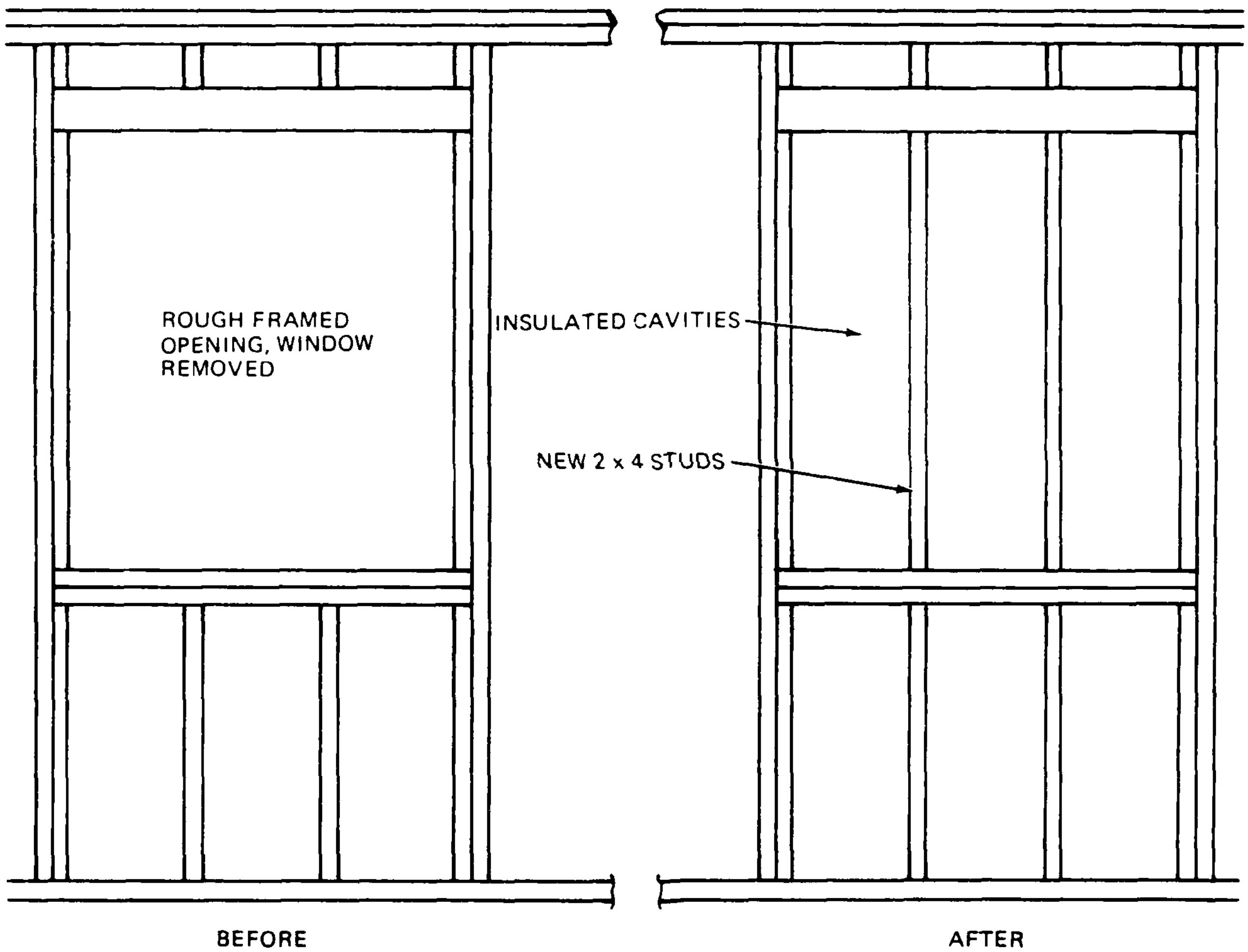
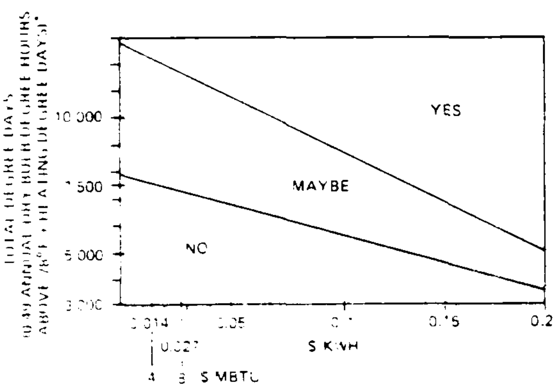


Figure BE-3. Reduce Window Area

BE 3. REDUCE WINDOW AREA

DESCRIPTION: In areas where windows are not required for view, daylight, or aesthetics, consider replacing them with insulated opaque wall sections. The wall area that replaces the windows will provide less heat transmission due to conduction and, depending upon its orientation and exposure, will reduce cooling loads due to solar gain. Reductions in window area are most beneficial on the north, east, and west surfaces.

FEASIBILITY REQUIREMENT:



*SEE MAPS 1 AND 3.

BENEFITS/DETRIMENTS: Transmission of heat and infiltration of outside air can be reduced by a reduction in window area. Detriments include aesthetic considerations and reduction in natural lighting.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Number of extraneous windows	Site Specific
- Window surface area	Site Specific
- Exposure direction of windows	Site Specific
- Langleys of solar radiation	Map 2, Supporting Data
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Windows: single glazed, double glazed, triple glazed	Site Specific
- Latitude	Map 1, Supporting Data
- Occupied hours per week	Site Specific
- Heating degree days	Map 1, Supporting Data
- Absorption coefficient of new walled-in area	Table 5
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine the number of extraneous windows, window area, and exposure direction of the windows to be removed.

2. Using nomographs 9 or 10 and 11, calculate the cooling load due to solar heat gain and conduction for the windows.

3. Using nomographs 12 or 13, calculate the heat loss through the windows.

4. Using nomographs 1 or 2 and 5 or 6, calculate the winter heat loss and summer heat gain through the insulated wall section that will replace the windows.

5. Fuel Savings (MBtu/yr) =

$$\frac{(\text{Heating Load Windows} - \text{Heating Load Wall})}{\text{Heating Plant Efficiency}}$$

6. Electrical Savings (kwh/yr) =

$$(\text{Cooling Load Windows} - \text{Cooling Load Wall}) \times \frac{1}{EER\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1{,}000\ wh}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: \$8.00/ft^2 for accessible walls (installed price: labor and materials)
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Carpenter and Brick Mason
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:	
Window Area	200 ft^2
Latitude	37° N
Absorption coefficient (of new wall area)	0.8
Exposure direction	West
Langleys	400
U-value for replacement wall	0.1
Occupied hours per week	40
Glazing (single, double)	Double
Heating degree days	4,000
Dry bulb degree hours above 78°F	8,000
Heating plant efficiency (HEFF)	75%
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: \$15/yr (\$0.075/ft^2-yr) decrease
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: \$5.12/MBtu, \$0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Annual solar heat gain/ ft^2 of window during summer	132(10^3) Btu/ft^2	Nomo 10

Annual conduction heat gain transmitted/ft^2 of window during summer	$4(10^3)$ Btu/ft^2	Nomo 11
Annual solar heat loss ft^2 of window in winter	$30(10^3)$ Btu/ft^2	Nomo 13
Annual solar winter heat loss/ft^2 wall section that replaces window	$5(10^3)$ Btu/ft^2	Nomo 2
Annual solar summer heat gain/ft^2 wall section that replaces window	$3(10^3)$ Btu/ft^2	Nomo 6

FUEL SAVINGS (MBtu/ft^2-yr) =

$$\frac{30(10^3) - 5(10^3)}{0.75} = 0.033 \text{ MBtu/ft}^2\text{-yr}$$

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$132(10^3) + (4(10^3) - 3(10^3)) \times \frac{1}{6.8 \ \frac{\text{Btu}}{\text{wh}}} \times \frac{1 \text{ kwh}}{1{,}000 \text{ wh}}$$

= 19.6 kwh/ft^2-yr

NES (MBtu/yr) =

0.033 MBtu/ft^2-yr + (19.6 kwh/ft^2-yr x

11,600 Btu/kwh x MBtu/10^6 Btu)

= 0.26 (MBtu/ft^2-yr)

0.26 MBtu/ft^2-yr x 200 ft^2

= 52 MBtu/yr

FUEL COST SAVINGS ($/yr) =

33,300 Btu/ft^2-yr x $5.12/MBtu = $0.17/$ft^2$

$0.17/$ft^2$-yr x 200 ft^2 = $34.00/yr

ELECTRICITY COST SAVINGS ($/yr) =

19.6 kwh/ft^2-yr x $0.08/kwh = $1.57/$ft^2$-yr

$1.57/$ft^2$-yr x 200 ft^2 = $313.0/yr

$$SIR = \frac{\$0.17(20.05) + \$1.57(18.049) + \$0.075(9.524)}{\$8(1)}$$

= 4.06

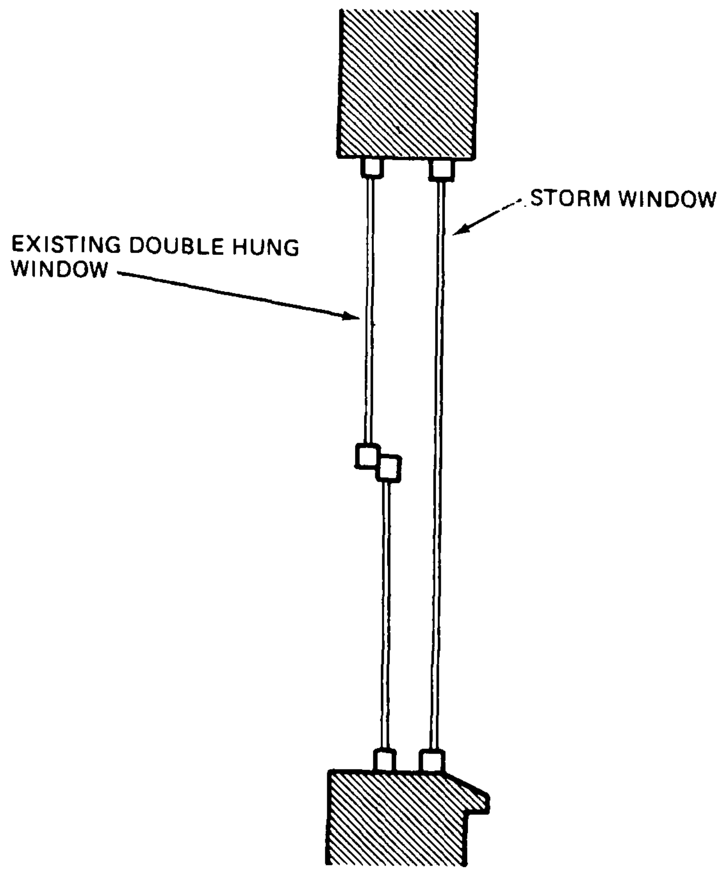
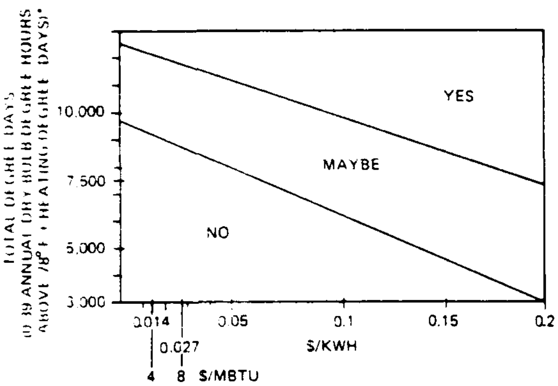


Figure BE-4. Install Double Glazing

DESCRIPTION: Heat flow through single glazed windows can represent a large portion of the building envelope. Single glazed windows can conduct more heat than a similar area of uninsulated wall. Adding a second layer of glazing either permanently or seasonally through the use of storm windows can cut the window's energy loss considerably. To prevent condensation between the panes of glass, the windows should be assembled with a dessicant in the window cavity and carefully sealed on all sides. Storm windows often have leak holes at the bottom to allow for the escape of condensed water.

FEASIBILITY REQUIREMENT:



*SEE MAPS 1 AND 3

BENEFITS/DETRIMENTS: Reduction in heat transmission through window areas while maintaining transparency. Possible increase in O&M cost.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Number of single glazed windows	Site Specific
- Window surface area	Site Specific
- Exposure direction of windows (E,W,N,S)	Site Specific
- Langleys of solar radiation	Map 2, Supporting Data
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Occupied hours per week	Site Specific
- Heating degree days	Map 1, Supporting Data
- Latitude	Map 1, Supporting Data
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine exposure direction, window surface area, and number of windows to be modified.

2. Use nomographs 9 through 13 to calculate annual winter heat loss and summer heat gain due to conduction and solar radiation for the existing single glazed windows.

3. Repeat step 2 for double glazing.

4. Fuel Savings (MBtu/yr) =

$$\frac{\text{Heat Loss (sgl) - Heat Loss (dbl)}}{\text{Heating Plant Efficiency}}$$

5. Electrical Savings (kwh/yr) =

$$\text{(Heat gain (sgl) - Heat Gain (dbl))} \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\text{ kwh}}{1{,}000\text{ wh}}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $6-$9/ft^2 combination storm and screen; $9-$15/ft^2 double glazing
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Glazing contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:	
Window area	200 ft^2
Latitude	37°N
Exposure direction	South
Langleys	400
Occupied hours per week	40
Heating degree days	4,000
Dry bulb degree hours above 78°F	10,000
Heating plant efficiency (HEFF)	75%
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: $15.00/yr ($0.075/ft^2-yr) increase
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Heat loss/ft^2 of window during winter (double glaze)	24(10^3) Btu/ft^2	Nomo 13
Heat loss/ft^2 of window during winter (single glaze)	46(10^3) Btu/ft^2	Nomo 13
Heat gain/ft^2 of window during summer due to sunlight radiant heat (double glaze)	124(10^3) Btu/ft^2	Nomo 10

Heat gain/ft^2 of window during summer due to sunlight radiant heat (single glaze)	$154(10^3)$ Btu/ft^2	Nomo 10
Heat gain/ft^2 of window during summer due to conduction (double glaze)	$5(10^3)$ Btu/ft^2	Nomo 11
Heat gain/ft^2 of window during summer due to conduction (single glaze)	$8(10^3)$ Btu/ft^2	Nomo 11

FUEL SAVINGS (MBtu/ft^2-yr) =

$$\frac{45(10^3) - 24(10^3)}{0.75} = 0.029 \text{ MBtu/ft}^2\text{-yr}$$

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$\left[(154(10^3) + 8(10^3)) - (124(10^3) + 5(10^3))\right] \times$$

$$\frac{1}{6.8\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1 \text{ kwh}}{1{,}000 \text{ wh}} = 4.9 \text{ kwh/ft}^2\text{-yr}$$

NES (MBtu/yr) =

0.029 MBtu/ft^2-yr + (4.9 kwh/ft^2-yr x

11,600 Btu/kwh x MBtu/10^6 Btu) = 0.086 MBtu/ft^2-yr

0.086 MBtu/ft^2-yr x 200 ft^2 = 17.2 MBtu/yr

FUEL COST SAVINGS ($/yr) =

0.029 (MBtu/ft^2-yr) x $5.12/MBtu = $0.15/ft^2-yr

$0.15/ft^2-yr x 200 ft^2 = $30/yr

ELECTRICITY COST SAVINGS ($/yr) =

4.9 kwh/ft^2-yr x $0.08/kwh = $0.39/ft^2-yr

$0.39/ft^2-yr x 200 ft^2 = $78/yr

SIR =

$$\frac{\$0.15(20.05) + \$0.39(18.049) + (-\$0.075)(9.524)}{\$7\ (1)}$$

= 1.3

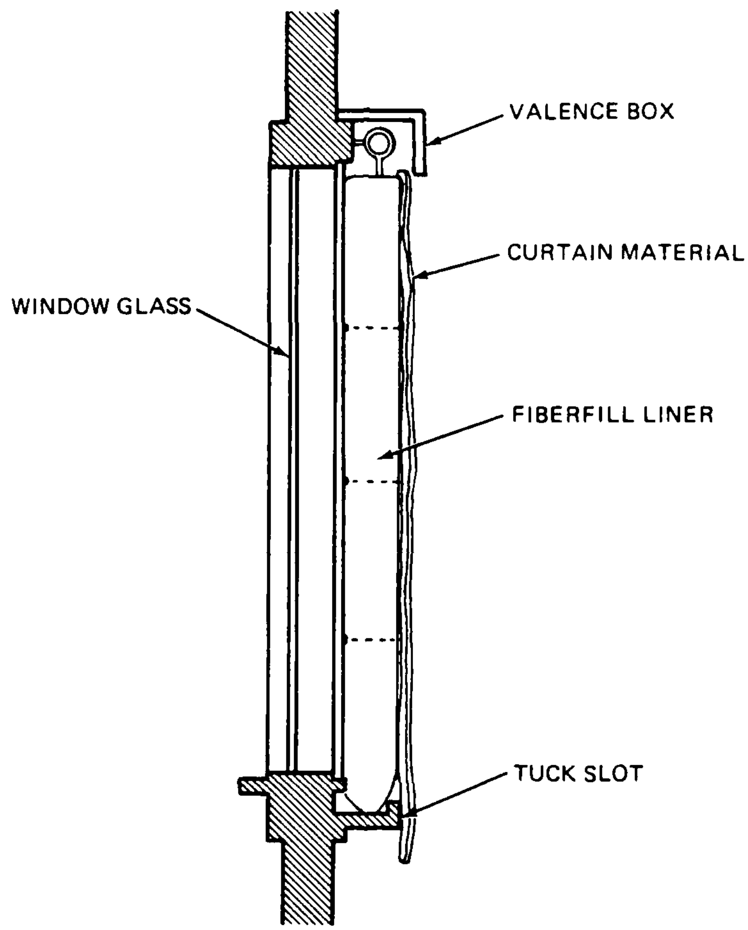


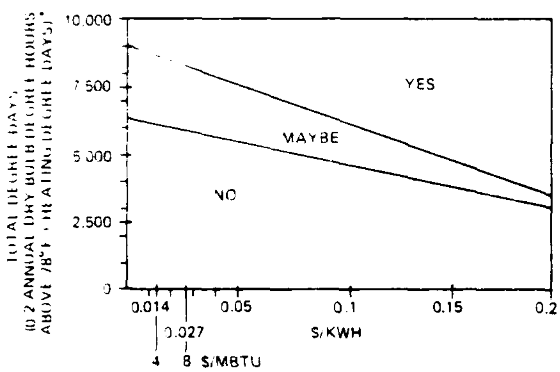
Figure BE-5. Install Insulating Drapes

DESCRIPTION: Windows, even double glazed units, have higher heat transmission rates than equal wall areas. To reduce heat loss while maintaining the advantages of window areas for daylighting, views, and ventilation, insulating drapes can be fitted to window areas. Various lined drapes and materials filled with insulation can be used. The surface facing the window is typically a light or reflective color to aide in summer heat control.

To be most effective as an insulating layer, the drapes should be sealed at the top and sides and allowed to drag the floor or fit into a slot at the bottom. The purpose of this is to prevent warmed room air from passing between the drape and window where it can be cooled and sink to the floor by natural convection.

Other materials such as multilayer reflective mylar window shades, sliding or hinged insulating foam panels, and roll-up window quilts can be used to perform the same task.

FEASIBILITY REQUIREMENT:



* SEE MAPS 1 AND 3

BENEFITS/DETRIMENTS: Reduced heat loss and potential solar heat gain control without loss of typical window functions. Possible increase in maintenance costs.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Estimate number of hours/day drape will be closed	Site Specific
- Number of windows requiring drapes	Site Specific
- Windows: single glazed/ double glazed	Site Specific
- Latitude	Map 1, Supporting Data
- Langleys of solar radiation	Map 2, Supporting Data
- Window exposure direction (E,W,S,N)	Site Specific
- Window area	Site Specific
- Occupied hours per week	Site Specific
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific
- U-value of window	Table 3
- R-value of drapes	Manufacturer Information

PROCEDURE:

1. Determine number, type, exposure direction, and area of window to be fitted with insulating drapes and determine average U-value for window and drape from table 3.

2. Use nomograph 12 or 13 to determine the annual heat loss for the plain window and nomograph 14 for the drapery fitted window.

3. Use nomograph 9 or 10 to find the solar heat gain through a window and nomograph 5 or 6 to find the solar heat gain through a window with drapes.

4. Fuel Savings (MBtu/yr) =

$$\frac{\text{Heat Loss (window) - Heat Loss (window w/drapes)}}{\text{Heating Plant Efficiency}}$$

5. Electrical Savings (kwh/yr) =

Heat Gain (window) - Heat Gain (window w/drapes) x

$$\times \frac{1}{EER\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1{,}000\ wh}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $4-$12/ft^2 installed (see table 4C)
Replacement Cost: Same as startup cost
Equipment Life: 10 years
Skill Level of Personnel Required: Drapery contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta EO\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

R-4 drapes closed	16 hours/day
Window area	200 ft^2
Latitude	37°N
Absorption coefficient	0.8
Exposure direction	West
Langleys	400
Occupied hours per week	40
Glazing	Single
Heating degree days	4,000
Dry bulb degree hours above 78°F	10,000
Heating plant efficiency (HEFF)	75%
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: $24.00/yr ($0.12/ft^2-yr) (increase)
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

U-value window:	1.15	Table 3
U-value window with drape:	0.45	Table 3
Heat loss/ft^2 windows	50(10^3) Btu/ft^2	Nomo 13

Heat loss/ft^2 windows with drapes	$43(10^3)$ Btu/ft^2	Nomo 14
Cooling solar heat gain/ft^2 windows	$155(10^3)$ Btu/ft^2	Nomo 10
Cooling solar heat gain/ft^2 windows with drapes	$21(10^3)$ Btu/ft^2	Nomo 6

FUEL SAVINGS (MBtu/ft^2-yr) =

$$\frac{50(10^3) - 43(10^3)}{0.75} = 9.3 \times 10^3 \text{ MBtu/ft}^2\text{-yr}$$

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$155(10^3) - 21(10^3) \times \frac{1}{6.8\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1 \text{ kwh}}{1,000 \text{ wh}}$$

$= 19.7$ kwh/ft^2-yr

NES (MBtu/yr) =

9.3×10^3 MBtu/ft^2-yr + (19.7 kwh/ft^2-yr x

11,600 Btu/kwh x MBtu/10^6 Btu) = 0.24 MBtu/ft^2-yr

0.24 MBtu/ft^2-yr x 200 ft^2 = 48 MBtu/yr

FUEL COST SAVINGS ($/yr) =

9,300 Btu/ft^2 x $5.12/MBtu = $0.05/$ft^2$-yr

$0.05/$ft^2$-yr x 200 ft^2 = $10/yr

ELECTRICITY COST SAVINGS ($/yr) =

19.7 kwh/ft^2 x $0.08/kwh = $1.58/$ft^2$-yr

$1.58/$ft^2$-yr x 200 ft^2 = $316/yr

SIR =

$$\frac{\$0.05(20.05) + \$1.58(18.049) + (-\$0.12)(9.524)}{\$6\ (1.561)}$$

$= 3.03$

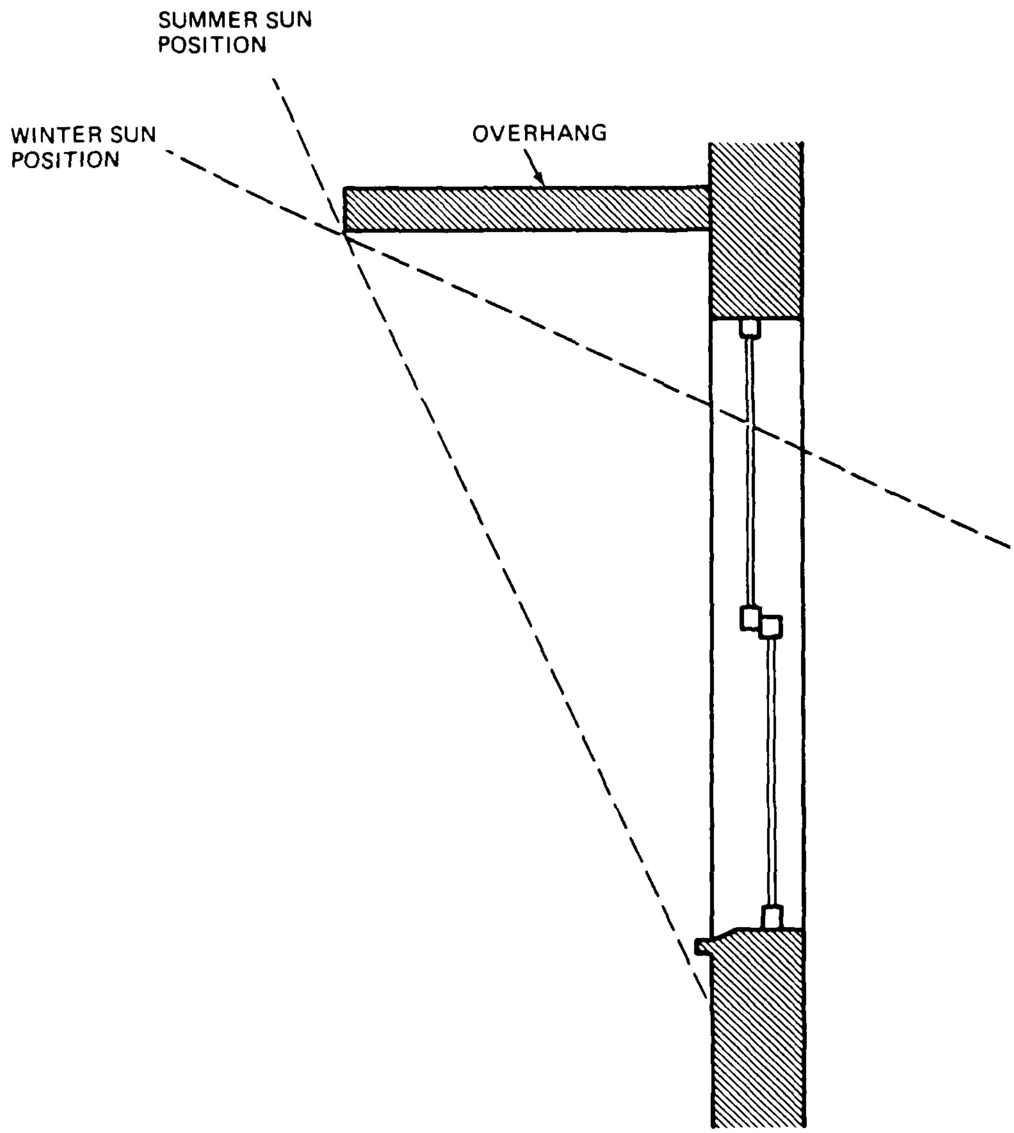


Figure BE-6. Control Solar Heat Gain

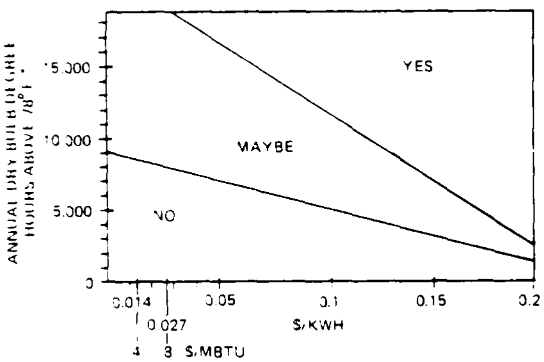
BE 5. CONTROL SOLAR HEAT GAIN

DESCRIPTION: Heat gain due to sunlight penetrating interior spaces through windows can result in high cooling loads and physical discomfort. Depending on the building's location and orientation, various means of solar control can be used.

To prevent direct sunlight from reaching the windows, external shading such as overhangs, awnings, and louvers can be used. Overhangs are particularly effective on south-facing windows because they can be sized to block the summer sun while admitting the lower winter sun. North facing windows should not be considered for this energy conservation option as solar heat gain is usually insignificant. The use of trees, shrubs, and other landscaping can provide attractive as well as effective sun screens.

Windows can also be fitted with reflective coatings or heat reflecting screens to reduce the amount of transmitted heat.

FEASIBILITY REQUIREMENT:



*SEE MAP 3

BENEFITS/DETRIMENTS: Direct solar radiation can be reduced from the interior space to minimize cooling load while admitting diffused daylight. Possible increase in maintenance costs.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Number of windows	Site Specific
- Window area	Site Specific
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Shading coefficient	Table 4B
- Type of shading device	Site Specific
- Exposure direction of windows (E,W,N,S)	Site Specific
- Langleys of solar radiation	Map 2, Supporting Data
- Type of glazing used	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine the number, type, area, and exposure direction for windows to be fitted with shading devices.

2. Use nomograph 9 or 10 to calculate the annual solar heat gain through the unprotected windows.

3. Heat gain through shaded windows = heat gain through plain windows x shading coefficient of shading device (table 4B).

4. Electrical Savings (kwh/yr) =

$$\left(\text{Heat Gain (unprotected)} - \text{Heat Gain (shaded)}\right) \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1 \text{ kwh}}{1{,}000 \text{ wh}}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: (Installed cost/ft^2): see table 4C
Replacement Cost: Same as startup cost
Equipment Life: 10 years
Skill Level of Personnel Required: Carpenter
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\text{SIR} = \frac{\Delta E\ (\text{DERF}) + \Delta\ \text{O\&M}\ (\text{PYDF})}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:

Reflective polyester film	
Window area	200 ft^2
Latitude	37° N
Exposure direction	West
Langleys	400
Glazing	Single
Dry bulb degree hours above 78°F	8,000
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: $15/yr ($0.075/ft^2-yr) (increase)
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Heat gain/ft^2 unprotected window	155(10^3)	Btu/ft^2	Nomo 10
Shading coefficient of shading device	0.24		Table 4B

Heat gain/ft^2 shaded window =

$$(0.24) \times 155(10^3) = 37.2(10^3)\ \text{Btu/ft}^2\text{-yr}$$

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$(155(10^3) - 37.2(10^3)) \times \frac{1}{6.8\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1 \text{ kwh}}{1{,}000 \text{ wh}}$$

$$= 17.32\ \text{kwh/ft}^2\text{-yr}$$

NES (MBtu/yr) =

(17.32 kwh/ft^2-yr) x (11,600 Btu/kwh x (MBtu/10^6 Btu))

= 0.2 MBtu/ft^2-yr

0.2 MBtu/ft^2-yr x 200 ft^2 = 40 MBtu

ELECTRICITY COST SAVINGS ($/yr) =

17.32 kwh/ft^2 x $0.08/kwh = $1.39/ft^2-yr

$1.39/ft^2-yr x 200 ft^2 = $278/yr

SIR =

$$\frac{\$1.39(18.049) + (-\$0.075)(9.524)}{\$2.5(1.561)}$$

= 6.25

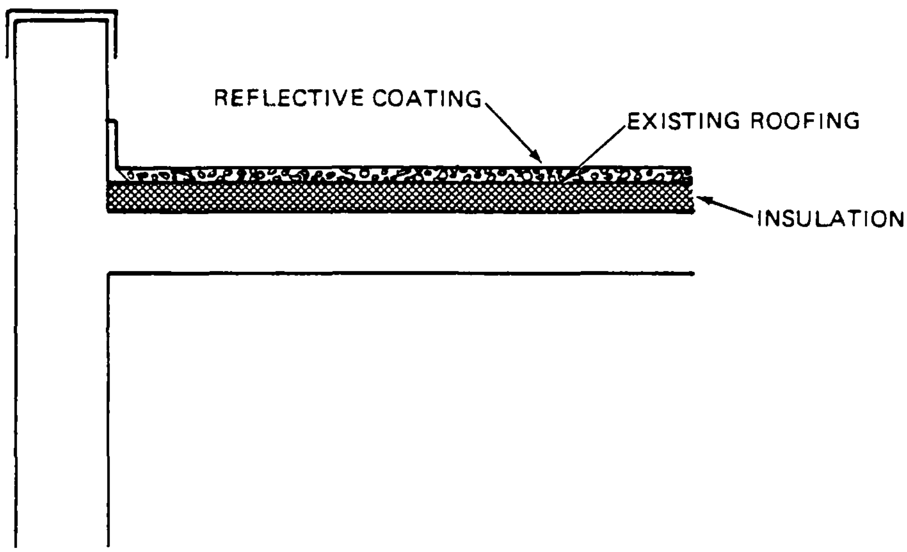


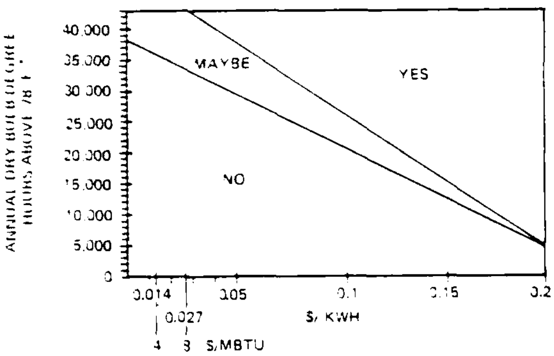
Figure BE-7. Install Reflective Coatings on Roofs

BE 7. INSTALL REFLECTIVE COATINGS ON ROOFS

DESCRIPTION: Because roofs cannot be shaded effectively by other means, various reflective coatings can be used to reduce solar heat gain. White aggregate or gravel can be used on built-up roofs to reduce the absorption coefficient. Light colors are recommended when replacing shingles.

Various spray-on reflective coatings have been developed primarily for use on buildings with metal roofs and on built-up roofs. In selecting a paint or reflective finish make sure that it is compatible with the existing roof and can withstand abrasion in traffic areas.

FEASIBILITY REQUIREMENT:



*SEE MAP 3

BENEFITS/DETRIMENTS: Increasing the reflectivity of a surface (decreasing absorption coefficient) will reduce the cooling load of the building.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Thickness and composition of existing roof	Site Specific
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Absorption coefficient of new roof coating	Table 5
- Absorption coefficient of existing roof	Table 5
- U-value of existing roof	Tables 1 and 2
- Langleys of solar radiation	Map 2, Supporting Data
- U-value of roof with coating	Tables 1 and 2
- Roof area (ft^2)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine absorption coefficient (table 5) and U-value of existing roof (table 1).

2. Use nomograph 8 to find the annual solar heat gain through the roof for the absorption coefficient of the proposed coating.

3. Repeat step 2 for the existing roof coating.

4. Electrical Savings (kwh/yr) =

(Heat Gain (Exist. Roof) - Heat gain (New Coat)) x

$$\frac{1}{EER\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1{,}000\ wh}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $0.13-0.91/ft^2$ applied.
Replacement Cost: Same as startup cost
Equipment Life: 10 years

Skill Level of Personnel Required: Roofing contractor

Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

Roof area new coating: white gravel	20,000 ft^2
Latitude	37°N
Absorption coefficient (old)	0.8
U-value of existing roof	0.14
Langleys	400
Dry bulb degree hours above 78°F	10,000
Cooling energy efficiency ratio (EER)	6.8

Change in O&M: $200/yr ($0.01/ft^2-yr) (increase)
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Solar heat gain using old coating absorption coefficient	$10(10^3)$ Btu/ft^2	Nomo 8
Solar heat gain using new coating absorption coefficient	$4.8(10^3)$ Btu/ft^2	Nomo 8

ELECTRICAL SAVINGS (kwh/ft^2-yr) =

$$10(10^3) - 4.8(10^3) \times \frac{1}{6.8\left(\frac{Btu}{wh}\right)} \times \frac{1\ kwh}{1{,}000\ wh}$$

= 0.77 kwh/ft^2-yr

NES (MBtu/yr) =

(0.77 kwh/ft^2-yr) x ((11,600 Btu/kwh) x (MBtu/10^6 Btu))

= 0.009 MBtu/ft^2-yr

0.009 MBtu/ft^2-yr x 20,000 ft^2 = 180 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

0.77 kwh/ft^2-yr x $0.08/kwh

= $0.06/$ft^2$-yr

= $0.06/$ft^2$-yr x 20,000 ft^2 = $1,200/yr

$$SIR = \frac{\$0.06(18.049) + (-\$0.01)(9.524)}{\$0.35(1.561)}$$

= 1.31

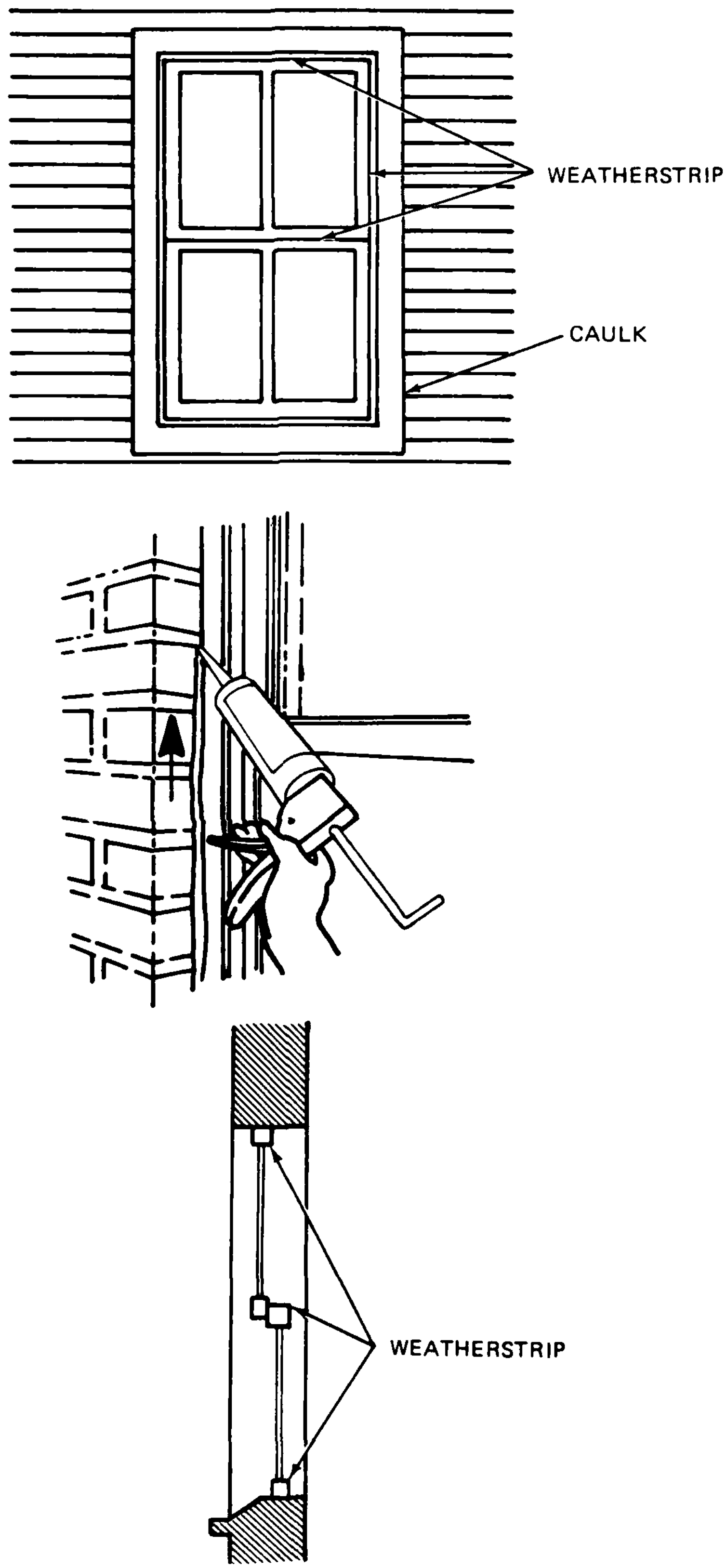
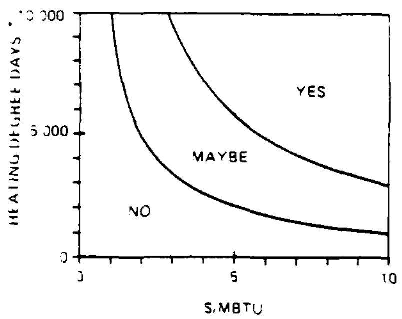


Figure BE-8. Caulk, Weatherstrip to Reduce Infiltration

DESCRIPTION: Infiltration of outside air accounts for a significant portion of a building's heat loss. Besides entering through open doors during entrance and exit, air enters through cracks around doors and windows, exterior wall penetrations, and junctions of building components. Windows and doors which must remain operable while excluding outside air should be weatherstripped. A variety of products, styles, and types of materials are available. Their selection depends on the specific application. Thresholds and door sweeps also reduce infiltration.

Cracks, gaps, and openings can be sealed more permanently using caulking compounds. Many different types of caulks have been developed to meet the needs of various applications. Most are designed to remain pliable to allow for the expansion and contraction or vibration of the substrate. To conserve caulking and get a better seal, large gaps should be filled first with packing such as oakum or styrofoam rope then caulked. Caulk should only be applied to clean dry surfaces.

FEASIBILITY REQUIREMENT:



*SEE MAP 1

BENEFITS/DETRIMENTS: Reduction of infiltration can produce savings in both heating and cooling energies.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Average wind speed	Site Specific
- Width of crack	Site Specific
- Length of crack	Site Specific
- Heating degree days	Map 1, Supporting Data
- Annual dry bulb degree hours above 78°F	Map 3, Supporting Data
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific
- Exposure direction of windows (E,W,N,S)	Site Specific
- Types of sealing jobs required	Site Specific
- Indoor temperature	Site Specific
- Hours of occupancy per week	Site Specific

PROCEDURE:

1. Establish the average wind speed for the site.

2. Estimate crack size (length and width) around windows, between doors and frames, and at ceiling/wall junctions and baseboards.

3. Determine the infiltration rate for the facility as follows:

   a. Use nomograph 15 to find the infiltration rate for windows to be weatherstripped (I_W).

   b. Use table 6A to find the infiltration rate for windows to be caulked (I_{caulk}). Use table 6 to find the infiltration rate between the door and frame (I_D).

   c. Assume an infiltration rate at ceilings/wall junctions combined with that around baseboards (I_C) of between 0.25 and 1 cfm/ft^2* of floor area. For estimating purposes 1 cfm/ft would represent loose wall construction (i.e. high infiltration) and 0.25 cfm/ft^2 would represent loose wall construction (i.e. nominal infiltration).

* Based on data from 1981 ASHRAE Fundamentals Handbook

4. Determine total infiltration (I_T) as follows:

   a. Caulking only:

   $$I_T = I_W + I_C$$

   b. Weatherstrippng only:

   $$I_T = (I_{W:existing} - I_{W:new}) + (I_{D:existing} - I_{D:new})$$

   c. Combination caulking/weatherstripping

   $$I_T = (I_{W:existing} - I_{W:new}) + (I_{D:existing} - I_{D:new}) + I_W + I_{caulk}$$

5. Use nomograph 16 to determine annual heating load per 1,000 cfm.

6. Fuel Savings (MBtu/yr) =

   (Nomograph 16 Result (MBtu/1,000 cfm-yr) x $0.5I_T$ (cfm))/ Heating Plant Efficiency

7. Electrical Savings (kwh/yr)

   $0.5I_T$ (cfm) x Annual Dry Bulb Degree Hours above 78°F/yr x

   $$1.08 \frac{\text{Btu - min}^{**}}{\text{ft}^3\text{-}^\circ\text{F-hr}} \times \frac{1 \text{ wh}}{\text{EER } \frac{\text{Btu}}{\text{wh}}} \times \frac{1 \text{ kwh}}{1{,}000 \text{ wh}}$$

** 1.08 = 0.075 lb air/cu ft x 0.24 Btu/lb-°F (specific heat of air) x 60 min/hr

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $1.17 to $3.00/lineal ft installed
Replacement Cost: Same as startup cost
Equipment Life: 5 years caulking, 15 years weatherstripping
Skill Level of Personnel Required: Carpenter
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta EO\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Caulk all infiltration points
- I_c = 0.9 cfm/ft^2 of floor area
- Floor area = 180 ft^2
- Window Specifications: 25 (6 ft h x 3 ft w) double-hung steel
- Crack size: 18 ft x 1/16 in. per window
- Wind Speed: 15 mph
- Indoor Temperature: 68°F winter, 78°F summer
- Hours of Occupancy Per Week: 168 hr/wk for winter and summer
- Heating plant efficiency (HEFF): 75%
- Cooling energy efficiency ratio (EER): 6.8
- Change in O&M: None
- Fuel Saved: No. 2 fuel oil, electricity
- Energy Cost: $5.12/MBtu, $0.08/kwh
- Escalation Rate: 8%, 7%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

- Referring to nomograph 15, determine the infiltration rate for double hung window for wind velocity of 15 mph.

  Infiltration (cfm/ft of crack) =

  $$\frac{0.62\ \text{cfm}}{\text{ft of crack}} \times 25\ \text{windows} \times 18\ \frac{\text{ft of crack}}{\text{window}}$$

  = 279 cfm

- The infiltration rate for ceiling/wall junction combined with that around baseboards is determined as follows:

  0.9 cfm/ft^2 of floor area x 180 ft^2

  = 162 cfm

  I_T = 279 cfm + 162 cfm

  = 441 cfm

- Referring to nomograph 16, determine the energy used per year for heating load.

  ENERGY USED = 125 Btu x 10^6/1,000 cfm/yr

FUEL SAVINGS (MBtu/yr) = (125 MBtu/1,000 cfm

x 0.5 (441) cfm)/0.075 = 36.8 MBtu

ELECTRICAL SAVINGS (kwh/yr) = (0.5) x (441 cfm)

$$\times\ 5{,}000°\ \text{F-hr/yr} \times 1.08\ \frac{\text{Btu - min}}{\text{ft}^3\text{-°F-hr}}$$

x 1/6.8 (Btu/wh) x 1 kwh/1,000 wh) = 175 kwh

NES (MBtu/yr) =

36.8 MBtu/yr + (175 kwh/yr x 11,600 Btu/kwh

x MBtu/10^6 Btu)

= 0.39 MBtu/yr

FUEL COST SAVINGS ($/yr) =

36.8 MBtu/yr x $5.12/MBtu = $188.1/yr

ELECTRICITY COST SAVINGS ($/yr) =

175 kwh/yr x $0.08/kwh = $14/yr

SIR =

$$\frac{\$188(20.050) + \$14(18.049)}{\$900\ (2.463)}$$

= 1.81

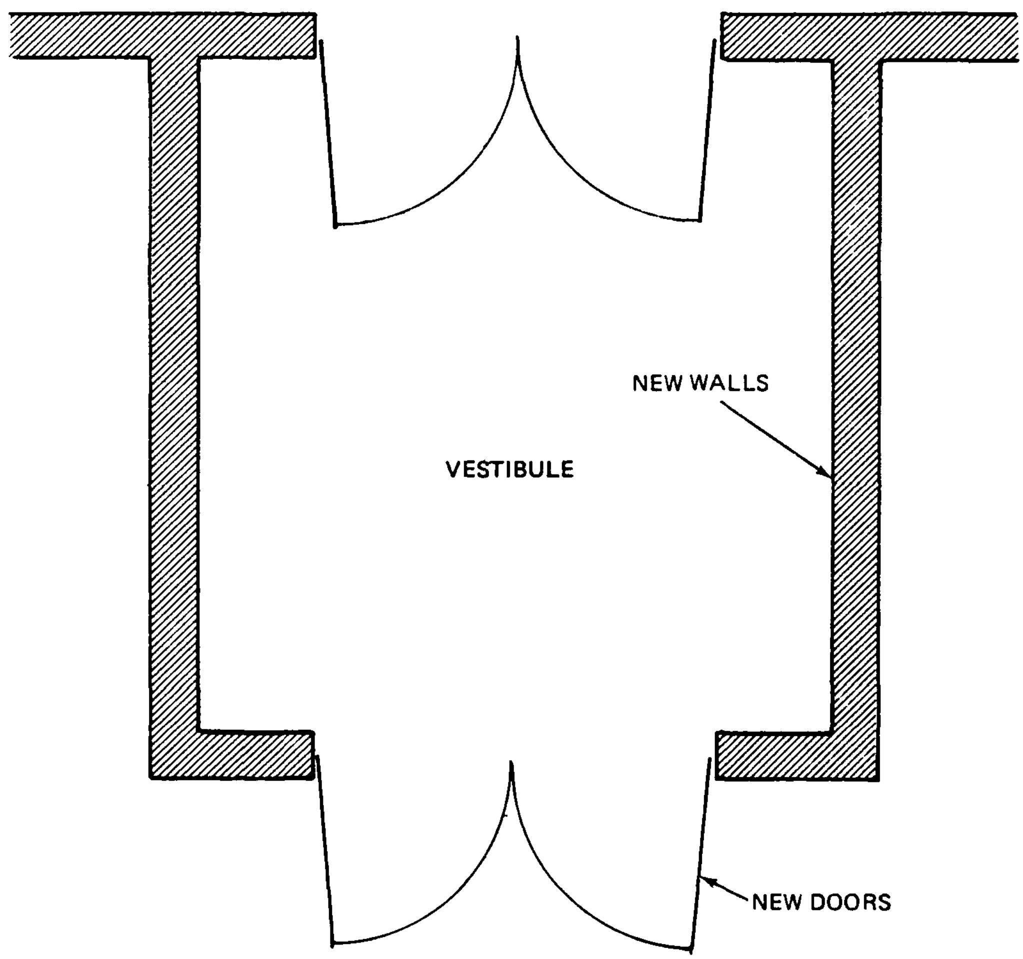
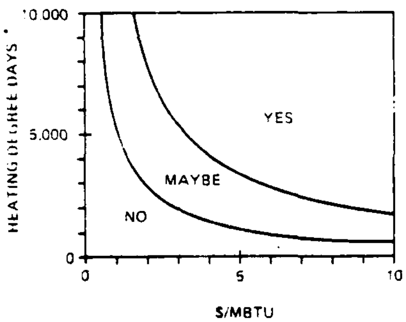


Figure BE-9. Install Vestibules

BE 9. INSTALL VESTIBULES

DESCRIPTION: Infiltration of outside air into buildings constitutes a major source of heat loss. Infiltration can be minimized by installing vestibules. A vestibule is a small room at the building entry-way with one set of doors opening to the building interior, and one set opening to the building exterior. As the exterior door is opened, only warm air from the vestibule can escape while cold winds may only penetrate as far as the interior door. When the interior door is opened, only the quantity of cold air in the vestibule may enter the building. The vestibule can function as a sheltered space for donning outerwear or waiting for transportation. Vestibules are a less costly alternative to the more efficient revolving door (see BE 10).

FEASIBILITY REQUIREMENT:



*SEE MAP 1

BENEFITS/DETRIMENTS: Infiltration is reduced without impeding the flow of personnel entering and exiting a building.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Passages/hour through building entrance	Site Specific
- Heating degree days	Map 1, Supporting Data
- Indoor temperature (summer and winter)	Site Specific
- Hours of occupancy per week	Site Specific
- Dry bulb degree hours above 78°F	Map 3, Supporting Data
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine the number of passages/hr for the entrance.

2. Using the following formula, calculate the difference in infiltration rates (IRs) between swinging doors and vestibules.

Infiltration (cfm) =

$$350\ \text{ft}^3/\text{passage} \times \frac{\text{passages}}{\text{hr}} \times \frac{\text{hr}}{60\ \text{min}}$$

3. Using nomograph 16 and associated survey data, determine the energy saved for heating as follows:

Fuel Savings (Btu/yr) =

$$\frac{\text{Infiltration (cfm)}}{\text{Heating Plant Efficiency}} \times \left[\frac{\text{Nomograph 16 (Btu} \times 10^6)}{1{,}000\ \text{cfm-yr}}\right]$$

4. Using the following formula, calculate the energy saved for cooling:

Electrical Savings (kwh/yr) =

Infil (from step 2) x Annual Dry Bulb Degree Hours Above 78°F

$$\times\ 1.08\ \frac{\text{Btu-min}^*}{\text{ft}^3\text{-}^\circ\text{F-Hr}} \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

$$^*\ 1.08 = 0.075\ \frac{\text{lb air}}{\text{ft}^3} \times 0.24\ \frac{\text{Btu}}{\text{lb-}^\circ\text{F}}\ \text{(specific heat of air)} \times 60\ \frac{\text{min}}{\text{hr}}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $5,800 single aluminum & glass door with closer, $6,600 double doors
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Carpenter
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(\text{DERF}) + \Delta E_{elec}(\text{DERF}) + \Delta\text{O\&M (PYDF)}}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Indoor temp: 65°F winter, 78°F summer
Dry bulb degree hours above 78°F: 5,000
Passages/hr: 200
Work Week: 40 hr
Heating plant efficiency (HEFF): 75%
Cooling energy efficiency ratio (EER): 6.8
Startup Cost: $6,600
Change in O&M: None
Fuel Saved: No. 2 fuel oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Infiltration =

$$(350\ \text{ft/passage}) \times \frac{\text{passage}}{\text{hr}} \times \frac{\text{hr}}{60\ \text{min}}$$

$$= (900\text{-}550\ \text{ft}^3/\text{passage}) \times \frac{200\ \text{passages}}{\text{hr}} \times \frac{\text{hr}}{60\ \text{min}}$$

= 1,167 cfm

FUEL SAVINGS (MBtu/yr) =

$$\frac{1{,}167\ \text{cfm}}{0.75} \times \frac{25 \times 10^6 \text{Btu}}{1{,}000\ \text{cfm-yr}} \times \frac{\text{MBtu}}{10^6\ \text{Btu}}$$

= 38.9 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

1,167 cfm x 5,000 °F-hr/yr x

$1.08 \frac{\text{Btu-min}}{\text{ft}^3\,{}^\circ\text{F-hr}} \times \frac{\text{wh}}{6.8\ \text{Btu}} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$

= 926.7 kwh/yr

NES (MBtu/yr) =

38.9 MBtu/yr + (926.7 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu)

= 49.6 MBtu/yr

FUEL COST SAVINGS ($/yr) =

38.9 MBtu/yr x $5.12/MBtu

= 199.2 $/yr

ELECTRICITY COST SAVINGS ($/yr) =

926.7 kwh/yr x $0.08/kwh

= 74.1 $/yr

SIR =

$\frac{\$199.2(20.050) + \$74.1(18.049)}{\$6{,}600\ (1)}$

= 0.81

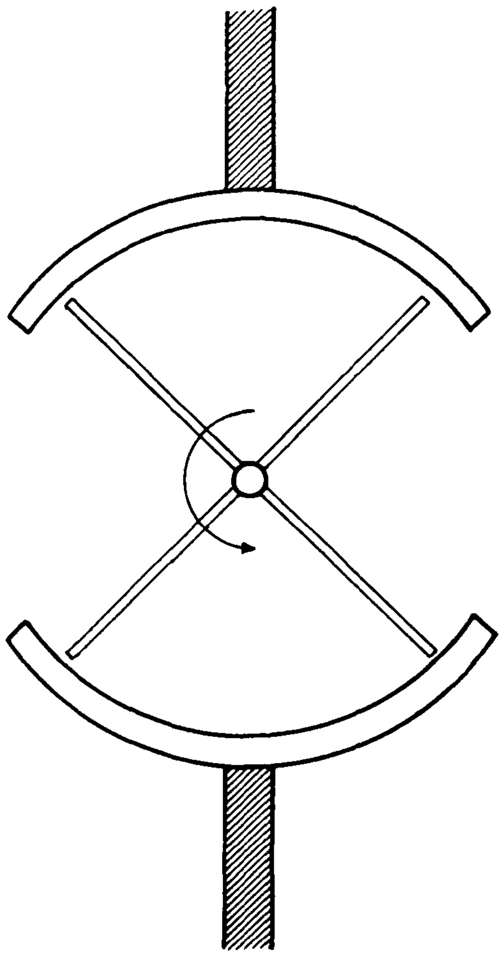
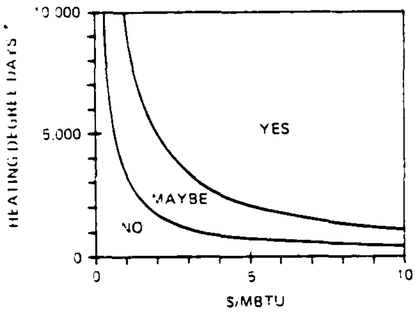


Figure BE-10. Replace Swinging Doors with Revolving Doors

BE 10. REPLACE SWINGING DOORS WITH REVOLVING DOORS

DESCRIPTION: Where swinging doors are currently used for pedestrian access only, they may be replaced with revolving doors. Swinging doors allow outside air to pass unobstructed into the interior of the building as the door is opened. In contrast, revolving doors allow only the air contained in the sector of the revolving door to enter. Consequently, revolving doors reduce infiltration and conserve energy. To maintain accessibility for handicapped persons, it will be necessary to have at least one sliding or swinging door.

FEASIBILITY REQUIREMENT:



*SEE MAP 1

BENEFITS/DETRIMENTS: Reduced infiltration with little restriction of the flow of personnel.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Passages per hour through building entrance	Site Specific
- Heating degree days	Map 1, Supporting Data
- Indoor temperature (summer and winter)	Site Specific
- Hours of occupancy per week	Site Specific
- Dry bulb degree hours above 78°F	Map 3, Supporting Data
- Heating plant efficiency (HEFF)	Site Specific
- Cooling energy efficiency ratio (EER)	Site Specific

PROCEDURE:

1. Determine the number of passages per hour.

2. Using the following formula, calculate the difference in infiltration rates between existing and revolving doors:

Infiltration (cfm) =

$$(\text{Infiltration Rate}_{\text{existing}} - \text{Infiltration Rate}_{\text{revolving}}) \times \frac{\text{passages}}{\text{hr}} \times \frac{\text{hr}}{60\ \text{min}}$$

Entrance Type	Infiltration Rate (ft^3/passage)
Without Vestibule	900
With Vestibule	550
Revolving (Manual)	60
Revolving (Motorized)	32

3. Using nomograph 16 and associated survey data, determine the energy saved for heating as follows:

Fuel Savings (MBtu/yr) =

$$\frac{\text{Infiltration (cfm)}}{\text{Heating Plant Efficiency}} \times \left[\frac{(\text{Nomograph 16})\ \text{Btu} \times 10^6}{1{,}000\ \text{cfm-yr}}\right]$$

4. Using the following formula calculate the energy saved for cooling:

Electrical Savings (kwh/yr) =

Infiltration (cfm) x Annual Dry Bulb Degree Hr x Above 78° F

$$\frac{1.08\ \text{Btu-min}^*}{ft^3\text{-}^\circ F\ \text{hr}} \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

* 1.08 = 0.075 lb air/ft³ x 0.024 Btu/lb-°F (specific heat of air) x 60 min/hr

GENERAL INFORMATION:

Sizes Available: 6-ft 6 in. to 7-ft diameter, 6 ft 10 in to 7 ft high
Startup Cost: Installed stock units, min $9,800, average $11,500, max $12,900, stainless steel $14,600 for automatic controls, add $1,100
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Carpenter, glazing contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(\text{DERF}) + \Delta E_{elec}(\text{DERF}) + \Delta \text{O\&M}\ (\text{PYDF})}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Existing entrance without vestibule
65°F indoor temp winter, 78°F summer
Dry bulb degree hours above 78°F: 5,000
Passages/hr: 200
Manual revolving door
40-hour work week
Heating plant efficiency (HEFF): 75%
Cooling energy efficiency ratio (EER): 6.8
Startup Cost: $9,825
Change in O&M: No change
Fuel Saved: No. 2 oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Using the table in step 2, the infiltration rate (IR)/passage can be determined.

Without Vestibule = 900 ft^3/passage
Revolving = 60 ft^3/passage

CFM = $(IR_{without\ vestibule} - IR_{revolving}\ (ft^3/Passage)) \times$

$$\left(\frac{passage}{hr}\right) \times \left(\frac{hr}{60\ min}\right)$$

$$= (900 - 60\ ft^3/passage) \times \frac{(200\ passages)}{hr} \times \frac{hr}{60\ min}$$

= 2,800 ft^3/min

FUEL SAVINGS (MBtu/yr) =

$$\frac{2,800\ cfm}{0.75} \times \frac{25 \times 10^6 Btu}{1,000\ cfm\text{-}yr} \times \frac{MBtu}{10^6\ Btu}$$

= 93 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

$$2,800\ cfm \times 5,000\ {}^oF\text{-}hr/yr \times 1.08\ \frac{Btu\ min}{ft^3\text{-}{}^oF\text{-}hr} \times$$

$$\frac{wh}{6.8\ Btu} \times \frac{kwh}{1,000\ wh}$$

= 2,223.5 kwh/yr

NES (MBtu/yr) =

93 MBtu/yr + (2,223.5 kwh/yr x 11,600 Btu/kwh MBtu/ 10^6 Btu)

= 118.8 MBtu/yr

FUEL COST SAVINGS ($/yr) =

93 MBtu/yr ($5.12/MBtu)

= $476.2/yr

ELECTRICITY COST SAVINGS ($/yr) =

2,223.5 kwh/yr ($0.08/kwh)

= $177.9/yr

SIR =

$$\frac{\$476.2(20.050) + \$177.9(18.049)}{\$9,825\ (1)}$$

= 1.30

References:

1. ASHRAE Fundamentals, 1979
2. Means Cost Estimating Handbook, 1982

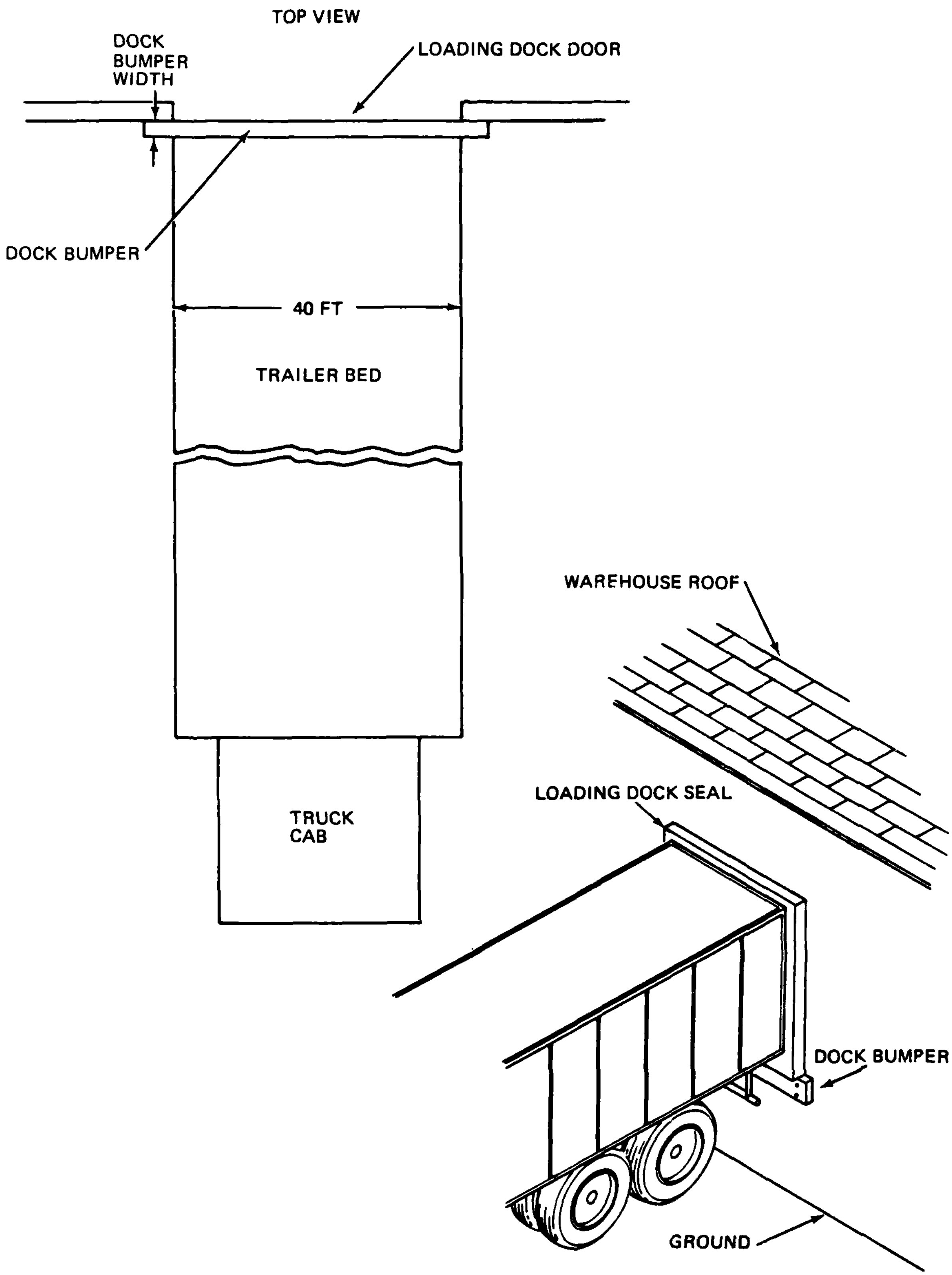


Figure BE-11. Install Loading Dock Door Seals

BE 11. INSTALL LOADING DOCK DOOR SEALS

DESCRIPTION: When trucks are being loaded at docks requiring the doors to be kept open, large quantities of outside air can flow inside. This results in a substantial increase in heating load. Depending on the type of dock construction various types of seals can be used to reduce this problem.

For open docks where materials are conveyed from truck to building through doorways, foam rubber or inflatable loading dock seals can be used to allow for the safe passage of material handling equipment while excluding outside air.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES

20 58

AVERAGE WEEKLY HOURS OF DOCK USE

BENEFITS/DETRIMENTS: Unimpeded material handling with reduced influx of outside air.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Type of existing dock doors	Site Specific
- Dimensions of loading dock doors (ft)	Site Specific
- Average wind speed (mph)	Site Specific
- Average winter outdoor temperature (°F)	Site Specific
- Number of loading dock doors	Site Specific
- Weekly hours of winter use (hr/wk)	Site Specific
- Thickness of dock bumper (ft)	Site Specific
- Average winter indoor temperature (°F)	Site Specific
- Winter length (weeks) (WKW)	
- Heating plant efficiency (HEFF)	Site Specific

PROCEDURE:

1. Determine the number and dimensions of each unsealed loading dock door.

2. Determine the average weekly hours of winter use for loading docks.

3. Determine the local average wind speed.

4. Determine the unsealed area of the dock doors. A three-sided (i.e., top, right and left sides) seal is used for most applications due to the variability of semitruck/trailer bumper and under carriage design.

   Unsealed Area (ft^2) =

   (Bumper Thickness) ((2 x Height) + Width)

5. Determine infiltration for unsealed dock door.

INFILTRATION (cfm) = Avg Wind Speed (mph) x 5,280 $\frac{ft}{mile}$ x $\frac{hr}{60\ min}$ x Unsealed Area (ft^2)

For estimating purposes it was assumed that installation of a three-sided dock seal would reduce infiltration 100%, therefore infiltration savings with a three sided dock seal equals the amount of infiltration in the unsealed area.

6. FUEL SAVINGS (MBtu/yr) =

Infiltration (cfm) x (Avg Winter Inside Temp - Avg Winter Outside Temp) x (1.08 $\frac{Btu - Min}{ft^3\text{-}^\circ F\text{-}hr}$)* x (Winter hr Dock Use/wk)

x (Weeks of Winter) x (MBtu/10^6 Btu)

x (1/Heating Plant Efficiency)

* 1.08 = 0.075 $\frac{lb\ air}{ft^3}$ x 0.24 $\frac{Btu}{lb\text{-}^\circ F}$ (Specific heat of air) x 60 min/hr

GENERAL INFORMATION:

Sizes Available: 8 x 8 ft to 20 x 20 ft
Startup Costs: $25 per perimeter ft, foam rubber seal
Replacement Cost: Same as startup cost
Equipment Life: 10 years
Skill Level of Personnel Required: Carpenter, mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Two doors 8 ft (w) x 10 ft (h) fitted with three-sided foam rubber seal
Winter Use: 10 hr/wk
Weeks of Winter (WKW): 20.9
Bumper Thickness: 0.5 ft
Average Winter Indoor Temperature: 58°F
Average Winter Outdoor Temperature: 38°F
Heating plant efficiency (HEFF): 75%
Wind Speed: 5 mph
Startup Cost: $700
Change in O&M: No change
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Unsealed Area Per Door (ft^2) =

(0.5 ft) x ((10 ft x 2) + 8 ft)

= 14 ft^2/Door

Infiltration for the unsealed area is computed as follows (procedure step 5).

= 5 mph x 5,280 $\frac{ft}{mile}$ x $\frac{hr}{60\ min}$ x 14 ft^2/Door

= 6,160 cfm/Door

FUEL SAVINGS (MBtu/yr) =

$(6{,}160 \text{ cfm})(58^{\circ}F - 38^{\circ}F) \times$

$(1.08 \dfrac{\text{Btu-min}}{\text{ft}^3\text{-}^{\circ}\text{F-hr}}) \times (20.9 \dfrac{\text{winter wk}}{\text{yr}} \times$

$10 \text{ hr/wk}) \times (1/0.75) \times (\text{MBtu}/10^6 \text{ Btu})$

= 37 MBtu/yr-Door

NES (MBtu/yr)

= 37 MBtu/yr-Door x 2 Doors = 74 MBtu/yr

FUEL COST SAVINGS ($/yr) =

74 MBtu/yr x $5.12/MBtu = $379/yr

=

$$\frac{\$379\ (20.05) + \$0\ (9.524)}{700\ (1.561)}$$

= 7.0

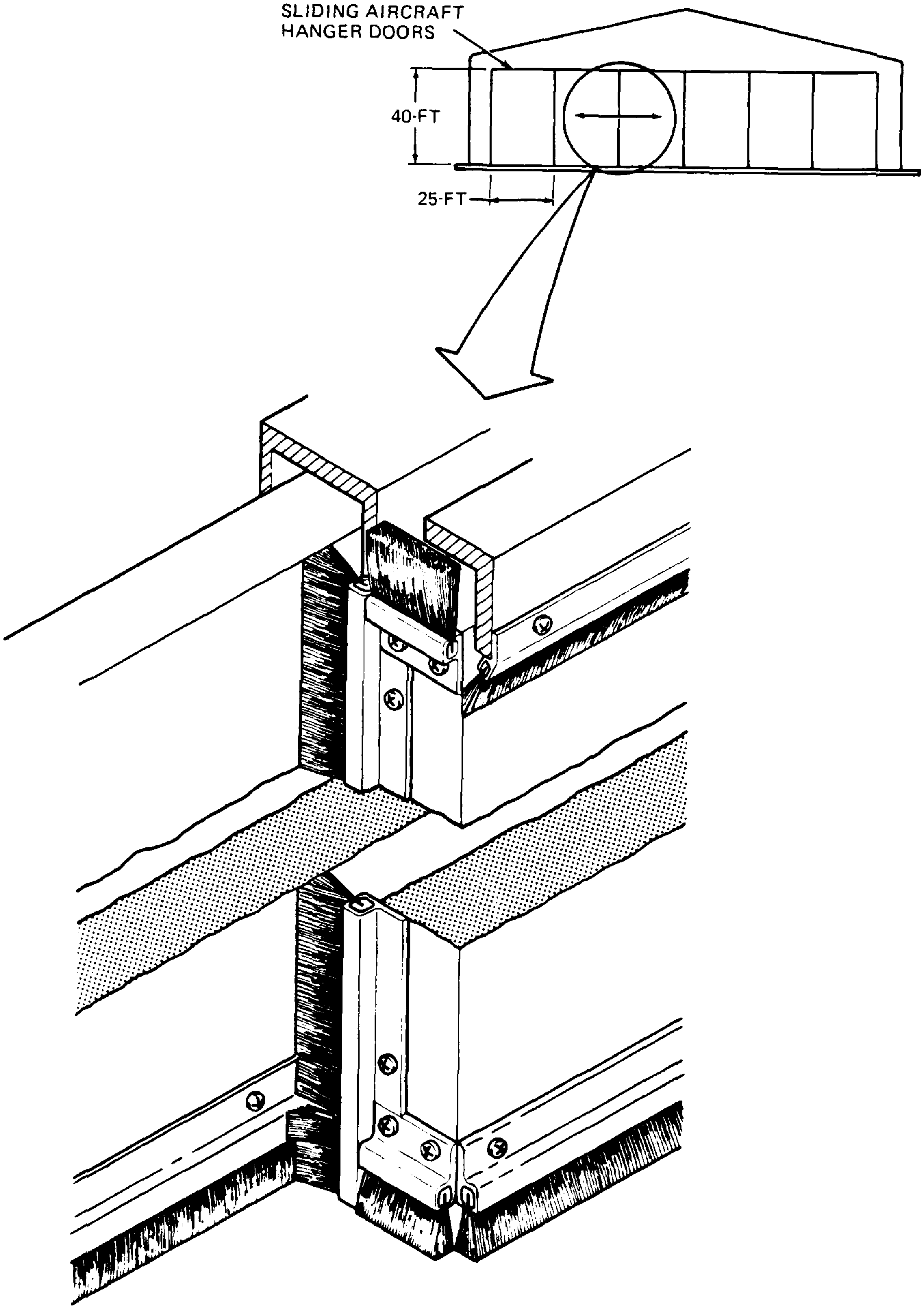
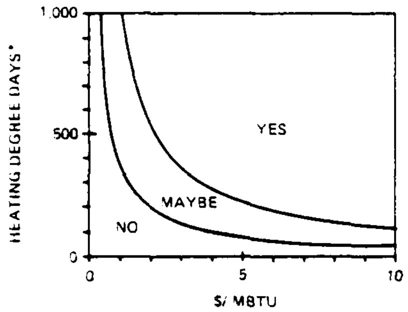


Figure BE-12. Hangar Door Seals

BE 12. HANGAR DOOR SEALS

DESCRIPTION: Air leakage through door seals is a major cause of hangar energy consumption. Infiltration can be reduced with the installation of nylon brush seals.

FEASIBILITY REQUIREMENT:



*SEE MAP 1

BENEFITS/DETRIMENTS: Reduced infiltration with little effect on normal operations. Advantages include no significant maintenance problems, no special tools required for installation, and the brush seal is flexible and can conform to changes and discontinuities in surface contours unlike rubber which gaps.

SURVEY DATA NEEDS:	SOURCE OF DATA:
- Hangar door size (H)	Site Specific
- Number of door panels	Site Specific
- Heating degree days	Map 1, Supporting Data
- Heating season average wind speed (mph)	Site Specific
- Heating plant efficiency (HEFF)	Site Specific
- Average winter wind speed (mph)	Site Specific

PROCEDURE:

1. Determine the hangar door size (width, height) and number of hangar door panels.

2. Determine the panel size as follows:

$$W_{panel} = \frac{\text{Hangar Door Width}}{\text{Number of Panels}}$$

$$H_{panel} = \text{Hangar Door Height}$$

3. Determine the perimeter footage (Sp) of nylon brush door seal required. Note that all four sides of each panel should have nylon brush seals installed.

$$Sp = (\text{Number of Panels/Door}) \times (2\ W_{panel} + 2\ H_{panel})$$

4. Fuel Savings (MBtu/heating season) =

$$\frac{Sp\ (ft)}{100} \times \frac{0.007\ D W_s^{1.1215}}{HEFF}$$

where:

Sp = Total Perimeter Footage of Nylon Brush Seal
D = Number of Heating Degree Days Per Heating Season
Ws = Heating Season Average Wind Speed (mph)
HEFF = Heating Plant Efficiency

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $15 to $25 per foot installed
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Mechanical contractor/PWC personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating plant efficiency (HEFF): 70%
Startup Cost: $23,400
Two hangar doors: 150 ft W x 40 ft H each
Six panels per door
Heating Degree Days: 4,000
Average Wind Speed: 10 mph
Change in O&M: None
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Using the equation in procedure step 2, determine the panel size:

$$W_{panel} = \frac{\text{Hangar Door Width}}{\text{Number of Panels}} = \frac{150\ ft}{6} = 25\ ft$$

$$H_{panel} = \text{Hangar Door Height} = 40\ ft$$

Using the equation in procedure step 3, determine the perimeter footage (Sp):

$$Sp = (\text{Number of Panels/Door}) \times (2\ W_{panel} + 2\ H_{panel})$$

$$= (6)(2 \times 25 + 2 \times 40)$$

$$= 780\ \text{ft/door}$$

FUEL SAVINGS (MBtu/yr-door) =

$$\frac{Sp}{100} \times \frac{0.007 W_s^{1.1215} D}{HEFF}$$

$$= \frac{780}{100} \times \frac{(0.007)(10)^{1.1215}(4{,}000)}{0.70}$$

$$= 4{,}127.2\ \text{MBtu/yr-door}$$

NES (MBtu/yr) =

4,127.2 MBtu/yr-door x 2 doors

= 8,254.4 MBtu/yr

FUEL COST SAVINGS ($/yr)

(8,254.4 MBtu/yr) ($5.12/MBtu)

= $42,262.5/yr

SIR =

$$\frac{\$42,262.5\ (20.05) + 0}{\$23,400\ (1.251)}$$

= 29

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DISTRIBUTION

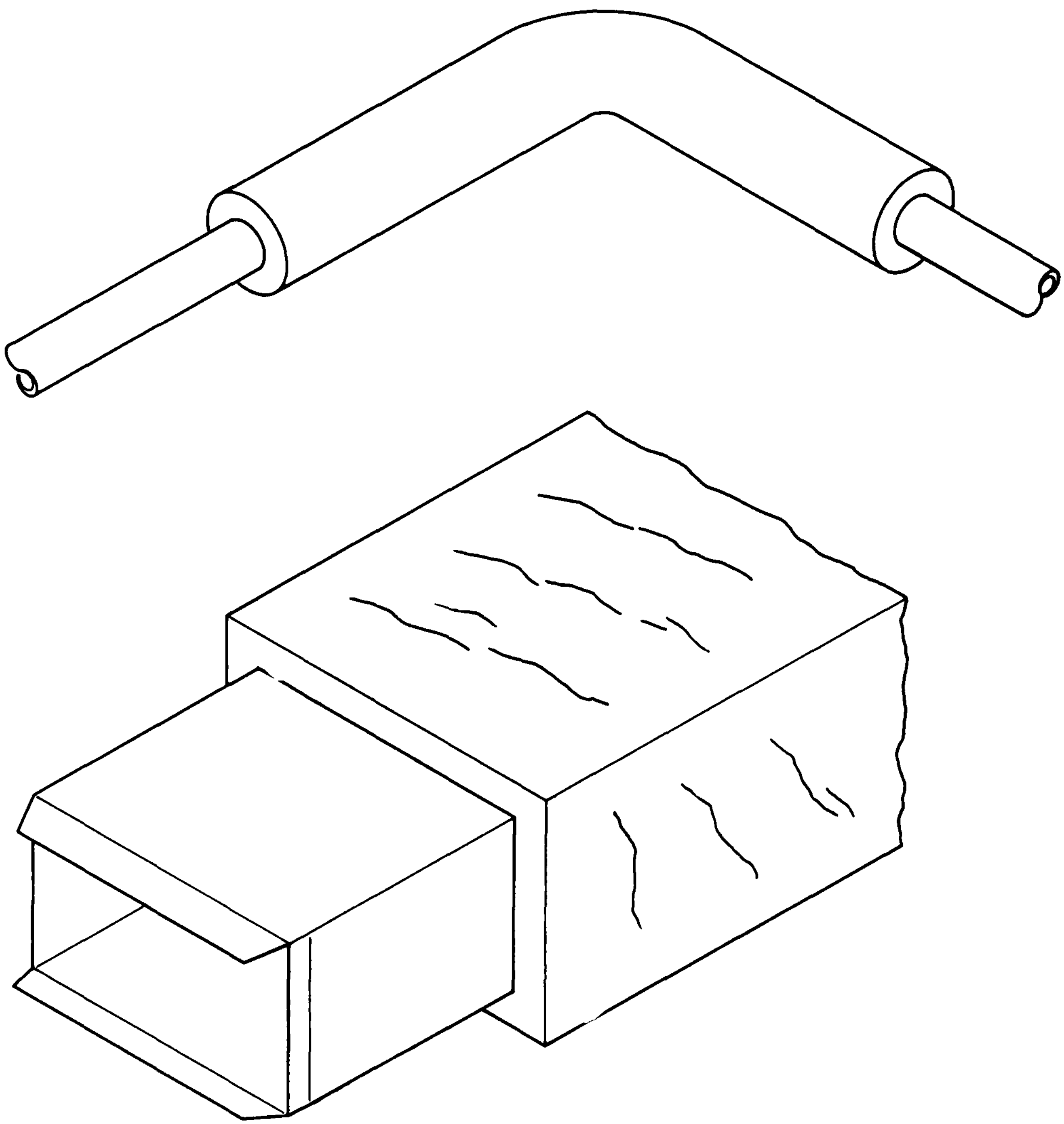


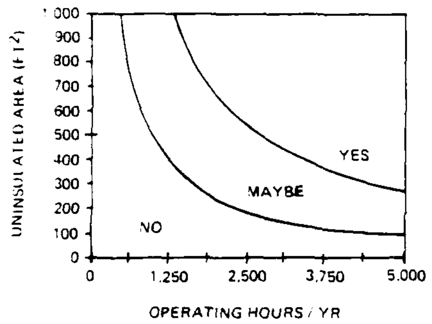
Figure D-1. Insulate Pipes and Ducts

DESCRIPTION: Until recently, warm air ducts and hot water piping were installed without insulation. These conveyances are frequently routed through unconditioned spaces where long runs can result in substantial heat loss. The same may be said for chilled water piping, steam lines, and cool air ducts.

Ducts may be insulated with rigid fibrous material or flexible mats held in place with wire, clips, or adhesive. Ducts may also be insulated with spray-on foam. Ducts used to convey both warm and cold air should have a vapor seal covering the insulation to prevent condensation in the insulation.

Pipes also can be insulated with a variety of rigid, fibrous, plastic, or glass wool materials. The selection of the insulation depends on the pipe's surface temperature and surrounding environment. Fittings, valves, and flanges should also be insulated. To preclude formation of excessive flash steam, steam traps or the first 6 feet of condensate discharge pipe from the trap should not be insulated.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Reduced energy loss through ducts and piping.

SURVEY DATA NEEDS:

- Size of piping/ducts
- Length of existing pipes/ducts
- Thickness of existing insulation on pipes/ducts
- Type of existing insulation on pipes/ducts
- Cooling energy efficiency ratio (EER)
- Operating temperature of water/steam in ducts and pipes
- Ambient temperature
- Operating hours of pipe/duct per year
- Type and thickness of planned insulation
- Plant efficiency (if unknown, assume 0.75)

PROCEDURE:

1. Determine the length of pipe/duct and ambient operating temperature and calculate the temperature difference.

2. Determine type and thickness of existing insulation on pipe/duct (if any).

3. Using nomographs 17 through 20 determine a first approximation of the heat loss or gain/hr of the pipe/duct, both in its present condition and equipped with the thickness of insulation under consideration.

4. See procedures accompanying nomograph 18 for piping cases which do not match nomograph 18 assumptions.

5. Fuel Savings for Pipes (Btu/yr) =

   $$(\text{Heat Loss or Gain}_{old} - \text{Heat Loss or Gain}_{new}) \times \left(\frac{\text{length of Insulation}}{10}\right) \times (\text{Operating hr/yr}) \times (1/\text{Plant Efficiency})$$

6. Electrical Savings for pipes (kwh/yr) =

   $$(\text{Cooling Loss or Gain}_{old} - \text{Cooling Loss or Gain}_{new}) \times \frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \left(\frac{\text{length of Insulation}}{10}\right) \times (\text{Operating hr/yr}) \times \frac{1\ \text{kwh}}{1{,}000\ \text{watts}}$$

7. Fuel Savings for Ducts (MBtu/yr) =
   $(\text{Heat Loss or Gain}_{old} - \text{Heat Loss or Gain}_{new}) \times$
   $(\text{ft}^2 \text{ of insulation}) \times (\text{Operating hr/yr}) \times$
   $(1/\text{Plant Efficiency})$

8. Electrical Savings for Ducts (kwh/yr) =
   $(\text{Cooling Loss or Gain}_{old} - \text{Cooling Loss or Gain}_{new}) \times$
   $(\text{ft}^2 \text{ of Insulation}) \times (\text{Operating hr/yr}) \times$

   $$\frac{1}{\text{EER}\left(\frac{\text{Btu}}{\text{wh}}\right)} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

GENERAL INFORMATION:

Sizes Available: 0.5-in. to 3.0-in. Insulation thickness
Startup Cost: See table 7 in tables section
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Insulation contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Energy Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\text{SIR} = \frac{\Delta E_{fuel}(\text{DERF}) + \Delta E_{elec}(\text{DERF}) + \Delta \text{O\&M}\ (\text{PYDF})}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Warm air duct 18-in. diameter x 250-ft length (1,200 ft^2)
Bare duct
0.5-in. insulation to be installed
Temperature difference: 50° F
Operating Hours/yr: 2,200 hr/yr
Heating Plant Efficiency (HEFF): 75%
Startup Cost: $2,400
Change in O&M: None
Fuel Saved: No. 2 fuel oil

Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

FUEL SAVINGS (MBtu/yr) =

$$\frac{(50\ \text{Btu/hr/ft}^2 - 24\ \text{Btu/hr/ft}^2)\ (1{,}200\ \text{ft}^2)\ (2{,}200\ \text{hr/yr})}{0.75} \times \frac{\text{MBtu}}{10^6\ \text{Btu}}$$

= 91.52 MBtu

NES (MBtu/yr) = 91.52 MBtu

FUEL COST SAVINGS ($/yr)

= 91.52 MBtu/yr x $5.12/MBtu

= $469/yr

SIR =

$$\frac{\$469\ (20.05) + 0\ (9.524)}{\$2{,}400\ (1)}$$

= 3.92

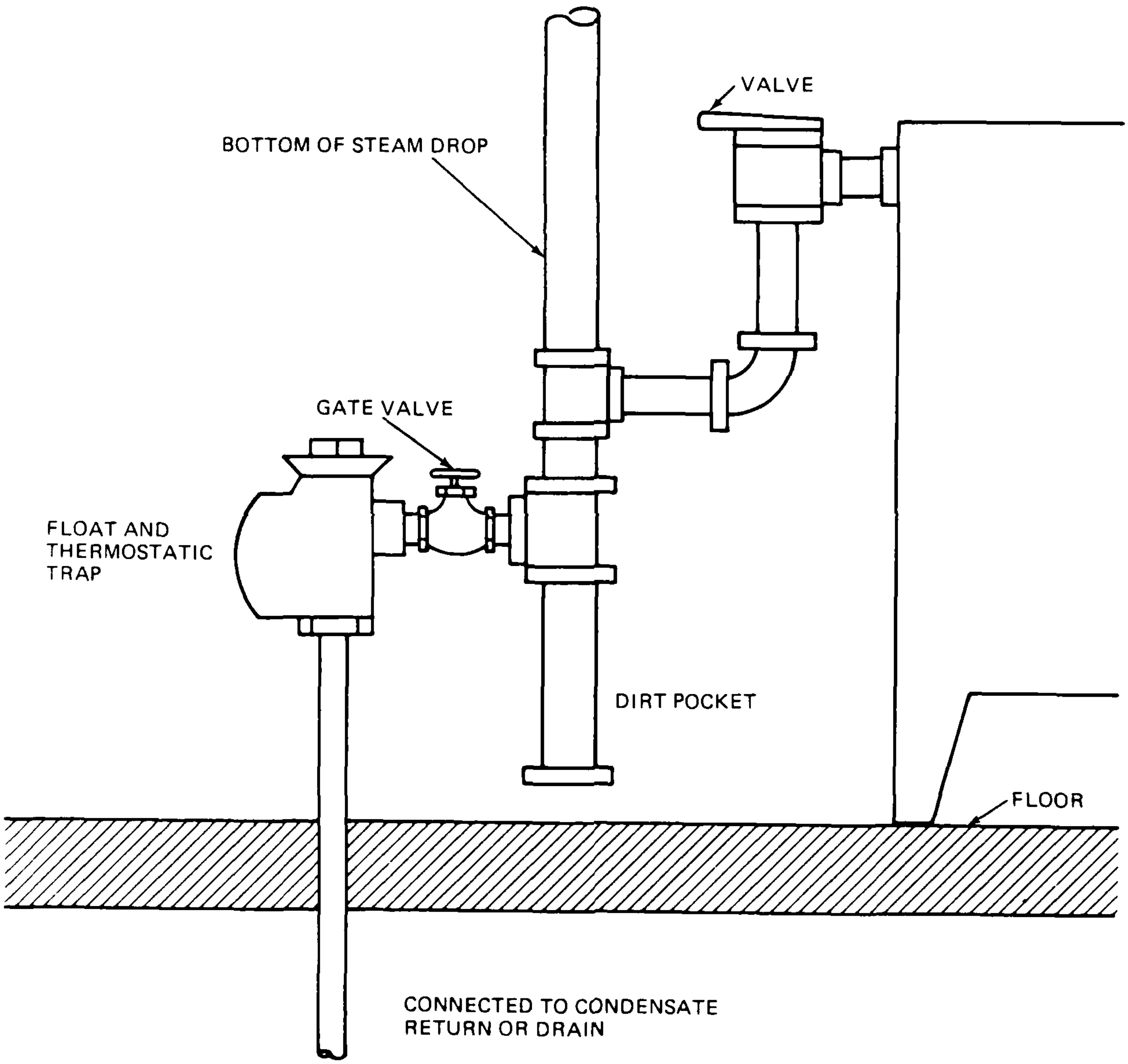


Figure D-2. Install/Replace Steam Traps

D 2. INSTALL/REPLACE STEAM TRAPS

DESCRIPTION: Steam traps are used to remove condensate, air and carbon dioxide from steam lines to improve system performance. When steam traps malfunction, live steam is allowed to escape. If only those traps are repaired that have been observed to fail, it is likely that many others are functioning inefficiently. Therefore a steam trap maintenance program is recommended to ensure additional energy saving. Test equipment can be obtained to check the traps' proper operation. The amount of energy saved depends on the number of traps that were found to be defective and on the trap size.

FEASIBILITY REQUIREMENT:
Always feasible.

BENEFITS/DETRIMENTS: Replacement of defective steam traps or installation of additional steam traps will result in a savings of steam and delivery of higher quality steam.

SURVEY DATA NEEDS:

- Number, size, and type of malfunctioning steam traps
- Steam trap orifice size (in.)
- Steam pressure (psig)
- Operating hours/yr
- Heating plant efficiency (HEFF)

PROCEDURE:

1. Determine the number, size, and type of malfunctioning steam traps.

2. From nomograph 21 determine the steam loss in lb/hr for the steam trap orifice size and working pressure used.

3. Fuel Savings (MBtu/yr) =

$$\frac{\text{Steam Loss (lb/hr)} \times 1{,}100 \text{ Btu/lb} \times \text{Operating hr/yr}}{\text{Heating Plant Efficiency}}$$

GENERAL INFORMATION:

Sizes Available: 3/16 in. to 2 in. orifices

Startup Cost: (Cost Installed)	Pipe Size (NPT) (In.) 1/2	1	1-1/4	1-1/2	2
Inverted Bucket	$76	$115	235	280	403
Float & Thermostatic	96	$112	135	$184	$306

Replacement Cost: Same as startup cost
Equipment Life: 5 years for waterfront application; 10 years for commercial application;

Skill Level of Personnel Required: Plumber
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test & Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in Btu/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Size of Malfunctioning Steam Trap: 3/16 in. orifice, 125 psig
Operating Hours: 3,000 hr/yr
Heating plant efficiency (HEFF): 75%
Equipment Life: 5 years
Startup Cost: $76
Change in O&M: $70 increase (with maintenance program)
Fuel Saved: No. 2 fuel oil
Energy Cost: $10/MBtu (Production Cost of Steam)
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Steam loss = 110 lb/hr (nomograph 21)

FUEL SAVINGS (MBtu/yr) =

$$\frac{110 \frac{\text{lb}}{\text{hr}} \times 1{,}100 \frac{\text{Btu}}{\text{lb}} \times 3{,}000 \frac{\text{hr}}{\text{yr}}}{0.75} \times \frac{\text{MBtu}}{10^6 \text{ Btu}}$$

= 484 MBtu/yr

NES (MBtu/yr) = 484 MBtu/yr

FUEL COST SAVINGS ($/yr) =

484 MBtu x $10/MBtu

= $4,840/yr

SIR =

$$\frac{\$4{,}840\ (20.050) + (-\$70)\ (9.524)}{\$76\ (1.561)}$$

= 812

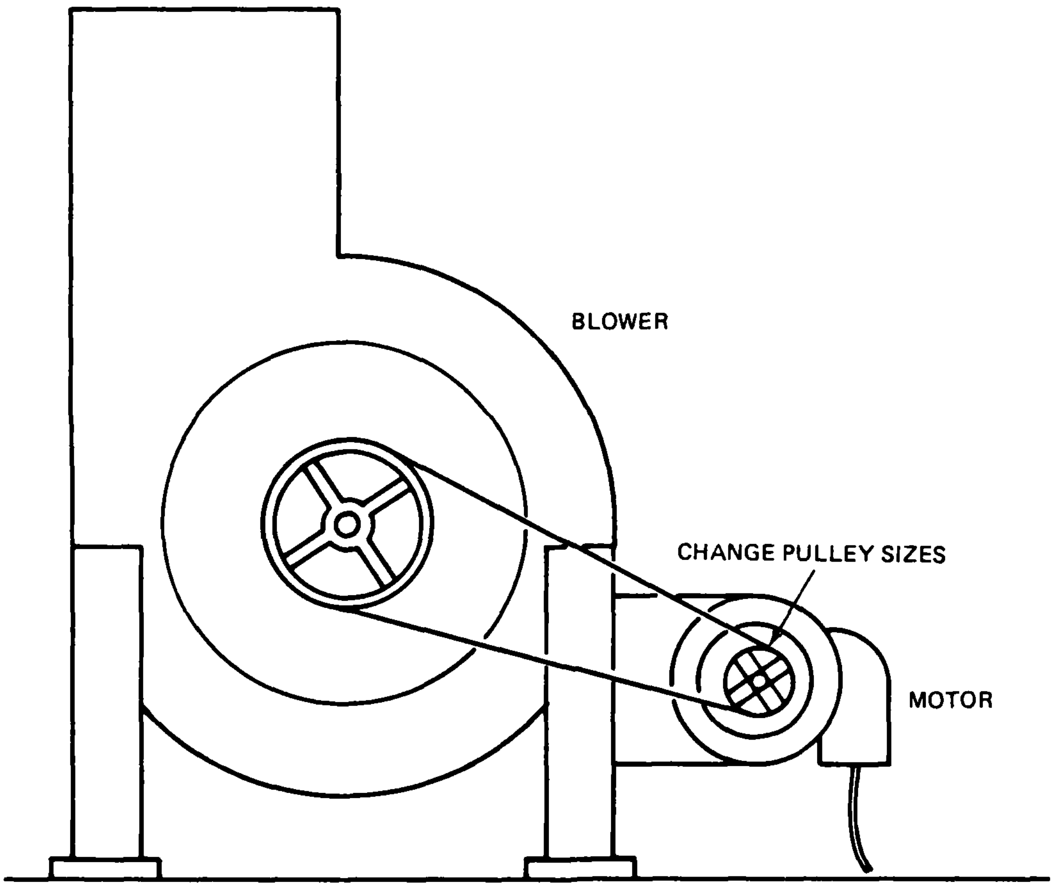
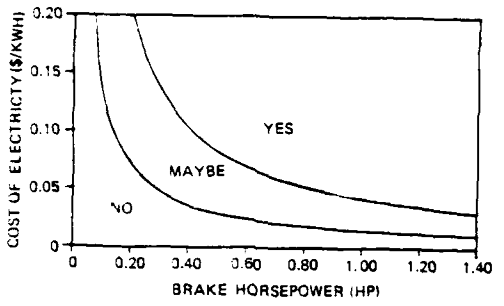


Figure D-3. Reduce Flow Rates on Fans

DESCRIPTION: Many existing ventilating and air conditioning systems may be oversized. This results in wasted energy. Some systems were intentionally oversized because of conservatism. Further, in some buildings where other energy conservation measures have been taken, the internal heat loads are significantly smaller than those which formed the basis for the original cooling system design. Finally, in some instances, the utilization of space, and the associated heat loads have changed without having corresponding changes made in HVAC equipment. Careful reevaluation of building heating/cooling loads and required HVAC system capacities may make lowered air supply rates feasible, particularly in the heating mode. Flow rates may be changed by changing motor-blower pulley size.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Reducing air flow rates will result in lowered costs for electric power to drive air circulation fans. Potential detriments if air flow rates are reduced beyond air flow requirements include personnel discomfort and possible degradation of materials and equipment.

SURVEY DATA NEEDS:

Manufacturer's performance data on fans which are used to maintain air flow.

- Fan type
- Variation of required driving power for proposed flow rate changes.
- Current fan flow rates
- Minimum air flow rate required by NAVOSH standard for personnel comfort.

PROCEDURE:

According to the Fan Laws (ASHRAE Systems & Equipment, chapter 4, table 1), the power required to drive a fan is proportional to the fan rpm^3. Ideally, a 10% reduction in fan speed would then require fan driving power equal to the original fan driving power times $(0.9)^3$, or 73% of the original power required. Because of imperfect designs and friction losses, this reduction in required power cannot be achieved in practice. Nevertheless, a substantial reduction in power may be achievable.

To determine the power reduction which can be expected with an actual fan:

1. Select candidate fans.
2. Obtain the manufacturer's performance data for the fan being considered.
3. Select the fan operating conditions which most closely approximate the existing fan operating point, and determine:
   - Fan Flow Rate in cubic feet per minute (CFM)
   - Fan rotation speed in revolutions per minute (RPM)
   - Brake horsepower required (BHP)
   - Static pressure in inches of water (SP)
4. Establish reduced air flow rate to meet minimum air flow rate required by NAVOSH standard.
5. Obtain the analogous data for reduced air flow rate. Alternately, fan law equations can be used to estimate reduced power requirement for reduced flow rate. See sample calculation.
6. Fuel Savings* (MBtu/yr) =

$$(BHP_{old} - BHP_{new}) \times \frac{42.418\ Btu}{hp\text{-}min} \times \frac{60\ min}{hr} \times$$

Operating hr/yr

* for steam-driven fan

7. Electrical Savings (kwh/yr) =

$$(BHP_{old} - BHP_{new}) \times \frac{42.418\ Btu}{hp\text{-}min} \times \frac{60\ min}{hr} \times$$

$$\frac{1\ kwh}{3{,}413\ Btu} \times \text{Operating hr/yr}$$

GENERAL INFORMATION:

Startup Cost: $300 ($200, material; $100, labor)
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Engineer for analysis; technician for installation
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}\ (DERF) + \Delta E_{elec}\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
10,000 cfm airflow
10% reduction in air flow rate
Static Pressure: 2 in. water
Operating Hours: 4,380/yr
Startup Cost: $300
Change in O&M: None
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Typical manufacturer's data and sample calculations for a CHICAGO centrifugal fan are as follows (approximate 10% reduction in rpm or cfm):

	CFM	FPM	RPM	BHP	SP
Old	10013	1900	687	1.60	2.0
New	8959	1700	621	1.21	2.0
Diff	10.6%	10.6%	9%	24.4%	(-)

ELECTRICAL SAVINGS (kwh/yr) =

$$(1.60 \text{ hp} - 1.21 \text{ hp}) \times \frac{42.418 \text{ Btu}}{\text{hp-min}} \times \frac{60 \text{ min}}{\text{hr}} \times$$

$$\frac{1 \text{ kwh}}{3{,}413 \text{ Btu}} \times 4{,}380 \text{ hr/yr}$$

= 1,273.8 kwh/yr

NES (MBtu/yr) =

$(1{,}273.8 \text{ kwh/yr})\ (11{,}600 \text{ Btu/kwh}\ (\text{MBtu}/10^6 \text{ Btu}))$

= 14.8 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

(1,273.8 kwh/yr) ($0.08/kwh)

= $101.9/yr

SIR =

$$\frac{\$101.9/\text{yr}\ (18.049) + 0\ (9.524)}{\$300\ (1)}$$

= 6.13

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HEATING, VENTILATION, AND AIR CONDITIONING

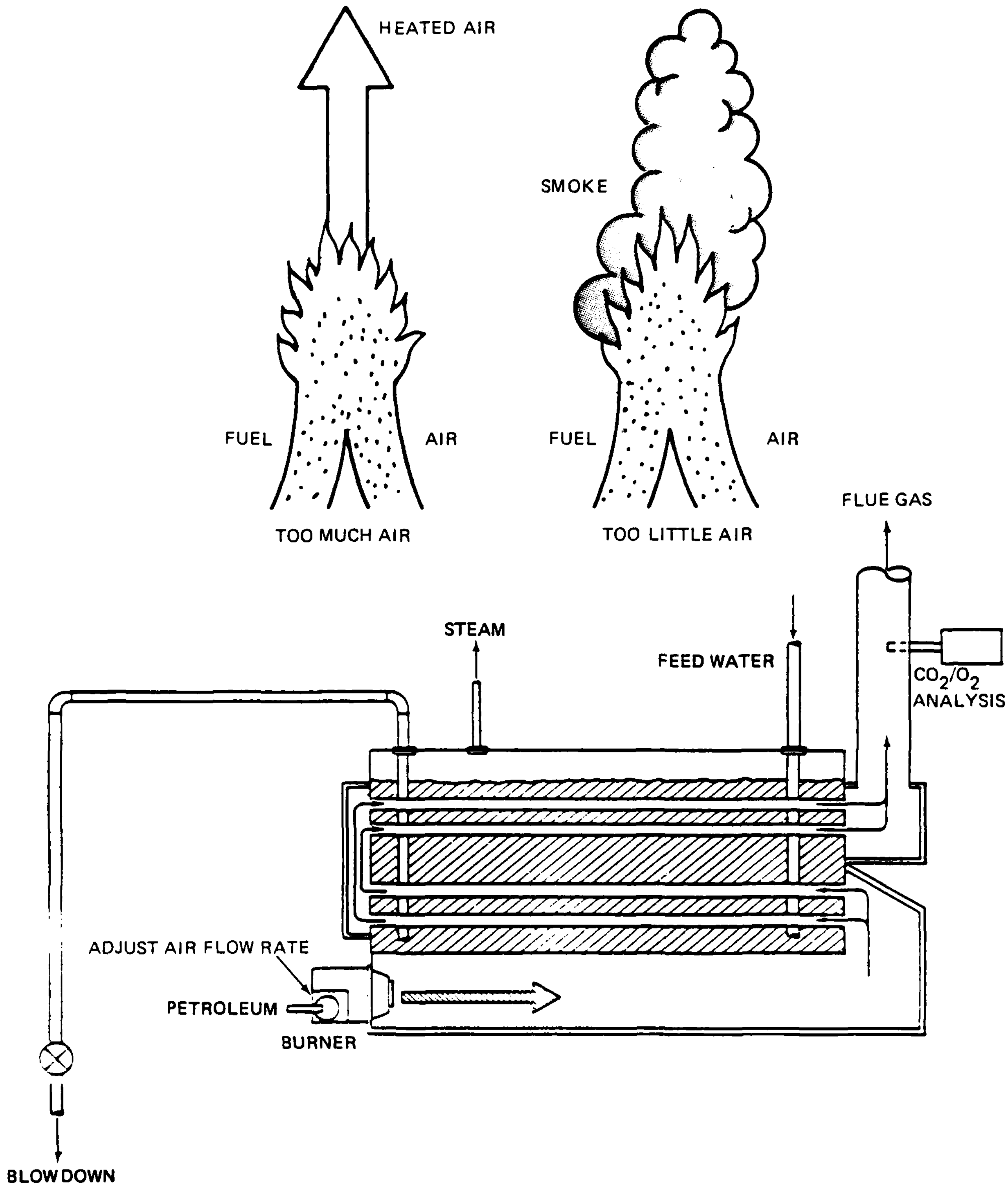


Figure HVAC-1. Adjust Air/Fuel Ratios

DESCRIPTION: Following building modifications to conserve energy, the boiler controls used will require adjustment. Most significant of these adjustments is the air/fuel ratio. Boilers not fitted with automatic mixture controls should be set to yield the highest efficiencies over the range of operating loads. Portable test equipment may be acquired or a mechanical contractor retained to perform the boiler operation tests and verify adjustments. Coal-fired boilers should be checked more frequently due to the variable nature of the fuel. A graph of percent load versus hours/year may be helpful in determining the optimum operating point.

To allow for precise adjustment, the boiler should be inspected for air leaks. Air should only enter through the designated primary and secondary inlets.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES	PRESENT BOILER EFFICIENCY BY STACK GAS ANALYSIS

90 85 80 75

BENEFITS/DETRIMENTS: Properly adjusted air/fuel mixtures will conserve energy and may result in cleaner boiler operation.

SURVEY DATA NEEDS:

- Boiler rated capacity (MBtu/hr)
- Annual Operating Hours (hr/yr)
- Average operating load (% capacity)
- % CO_2 in flue gas
- % O_2 in flue gas
- Boiler Efficiency (%) by stack gas analysis
- Stack temperature (°F)

PROCEDURE:

1. Analyze the flue gases to determine percent CO_2 or O_2 and stack temperature before adjustment.

2. Using nomograph 22, calculate the boiler efficiencies in present and tuned up conditions.

Maximum CO_2 Ranges for Common Fuels for Tuned-Up Boilers

Fuel	% CO_2 by Volume
Natural gas	11.6 to 12.7
Oil	14.25 to 16.35
Bituminous coal	17.7 to 19.3
Anthracite coal	19.3 to 19.85

3. Fuel Savings (MBtu/yr) =

(% Efficiency increase x Avg Operating Load x Boiler Rated Capacity x Oper hr/yr)/(Boiler Efficiency)

GENERAL INFORMATION:

Sizes Available: N/A
Startup Costs: \$100-\$500/boiler (test instrumentation)
Replacement Cost: Same as startup cost
Equipment Life: 5 years
Skill Level of Personnel Required: Boiler Technician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
0.5 MBtu/hr Boiler
3,000 hr/yr, 500°F stack temp, 10.5% CO_2 in stack. Average load 60% of rated capacity, 75% efficiency
Startup Costs: \$300 (test kits)
Change in O&M: \$100 (increase)
Fuel Saved: No. 2 oil
Energy Cost: \$5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Calculation of Increase in Efficiency:

From Nomograph 22	CO_2 (%)	EFFIC (%)
Present	10.5	82
Possible	15.5	85

3% Increase Possible

FUEL SAVINGS (MBtu/yr) =

(Eff. increase) x (Avg Operating Load) x (Boiler Rated Capacity) x (Oper hr/yr) x (1/Boiler Efficiency)

$$= \frac{0.03 \times 0.60 \times 0.5\ \text{MBtu/hr} \times 3{,}000\ \text{hr/yr}}{0.75}$$

= 36 MBtu/yr

NES = 36 MBtu/yr

FUEL COST SAVINGS (\$/yr) =

36 MBtu x \$5.12/MBtu = \$184/yr

$$SIR = \frac{\$184(20.05) + (-\$100)(9.524)}{\$300(2.463)}$$

= 3.70

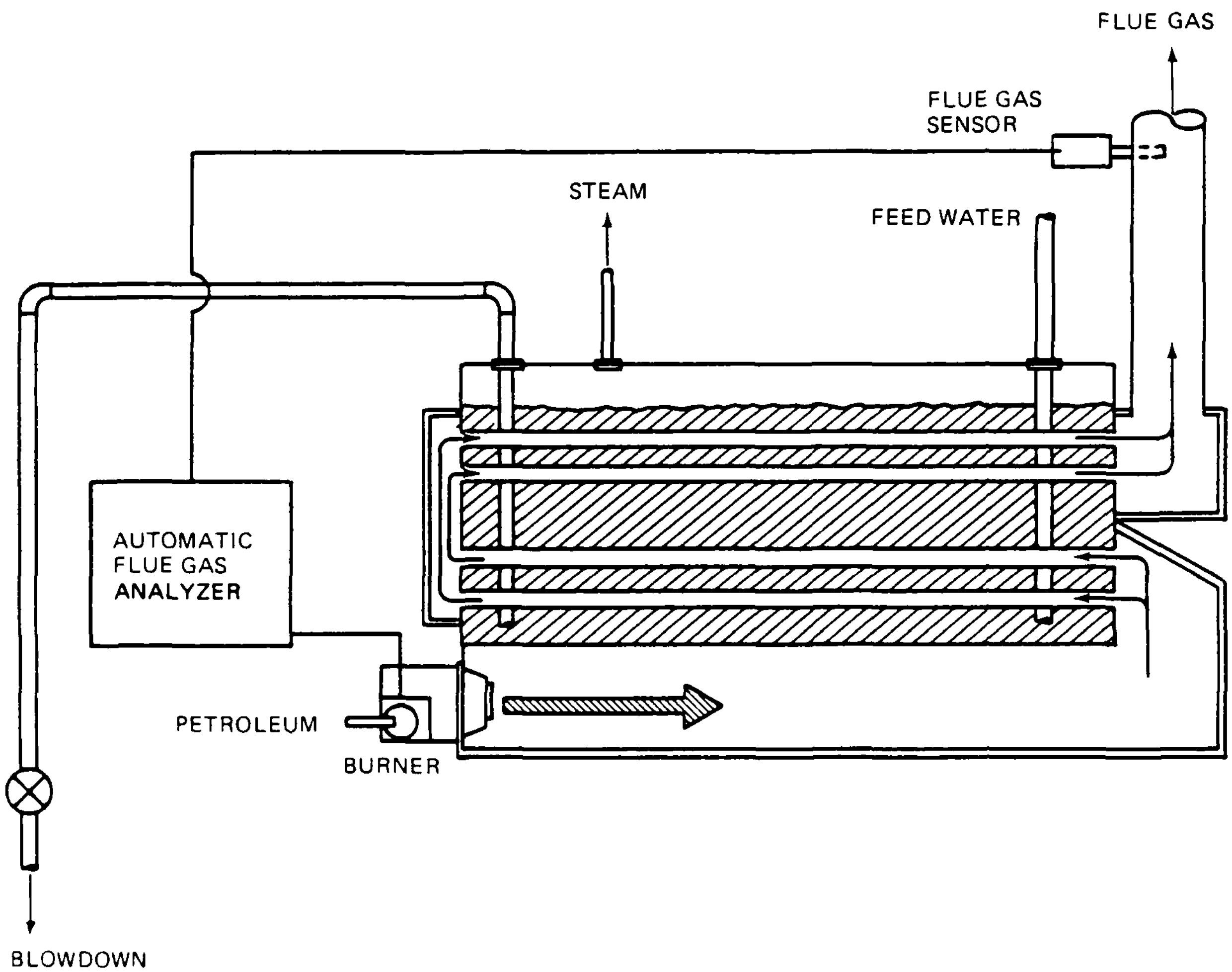


Figure HVAC-2. Install Automatic Flue Gas Analyzing Equipment

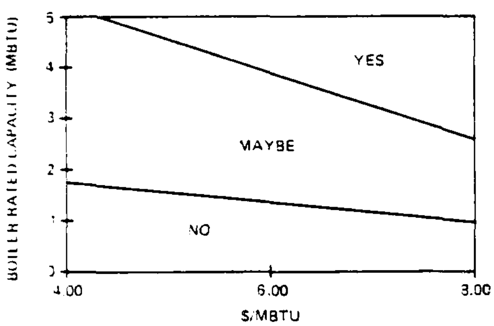
HVAC 2. INSTALL AUTOMATIC FLUE GAS ANALYZING EQUIPMENT

DESCRIPTION: Efficient combustion of fuel requires an optimum air/fuel ratio providing enough air to ensure complete combustion without overdiluting the mixture. Ideally as load and stack draft conditions change, the air fuel mixture should also be varied.

On smaller boilers, devices that continuously measure carbon dioxide and stack temperature can be installed. These devices provide a direct readout of boiler efficiency and can be used by operators to manually adjust air/fuel ratios.

A more accurate measure of combustion efficiency can be obtained by monitoring stack gas oxygen content. These analyzers are particularly useful on multi-fueled boilers since excess oxygen varies only slightly. On large boiler installations, automatic oxygen analyzers can be used to directly control air/fuel mixtures with changing conditions.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: The installation of flue gas analyzing equipment allows more close control of boiler and/or fuel ratios resulting in more efficient operation.

SURVEY DATA NEEDS:

- Boiler rated capacity (MBtu/hr)
- Annual hours of operation (hr/yr)
- Average operating load (% rated capacity)

PROCEDURE:

1. Determine boiler annual energy consumption =

((Avg Operating Load) x (Boiler Rating) x (Oper hr/yr))/(Boiler efficiency)

2. Fuel Savings (MBtu/yr) = 0.02 x Annual Energy Consumption

GENERAL INFORMATION:

Sizes Available: N/A
Startup Costs: $8,000/boiler
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Mechanical contractor/electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Boiler size: 0.5 MBtu/hr
- 3,000 hr/yr
- 75% efficiency
- Average load: 60% of rated boiler capacity
- Startup Cost: $8,000
- Change in O&M: None
- Fuel Saved: No. 2
- Energy Cost: $5.12/MBtu
- Escalation Rate: 8%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

FUEL SAVINGS (MBtu/yr) =

(0.02) x (Avg Operating Load) x (Boiler Rated Capacity) x (Oper hr/yr) x (1/Boiler Efficiency)

$$= \frac{0.02 \times 0.60 \times 0.5\ \text{MBtu/hr} \times 3{,}000\ \text{hr/yr}}{0.75} = 24\ \text{MBtu/yr}$$

NES = 24 MBtu/yr

FUEL COST SAVINGS ($/yr)

= 24 MBtu/yr x $5.12/MBtu = $123/yr

$$SIR = \frac{\$123\ (20.05) - 0}{\$8{,}000\ (1.251)}$$

= 0.246

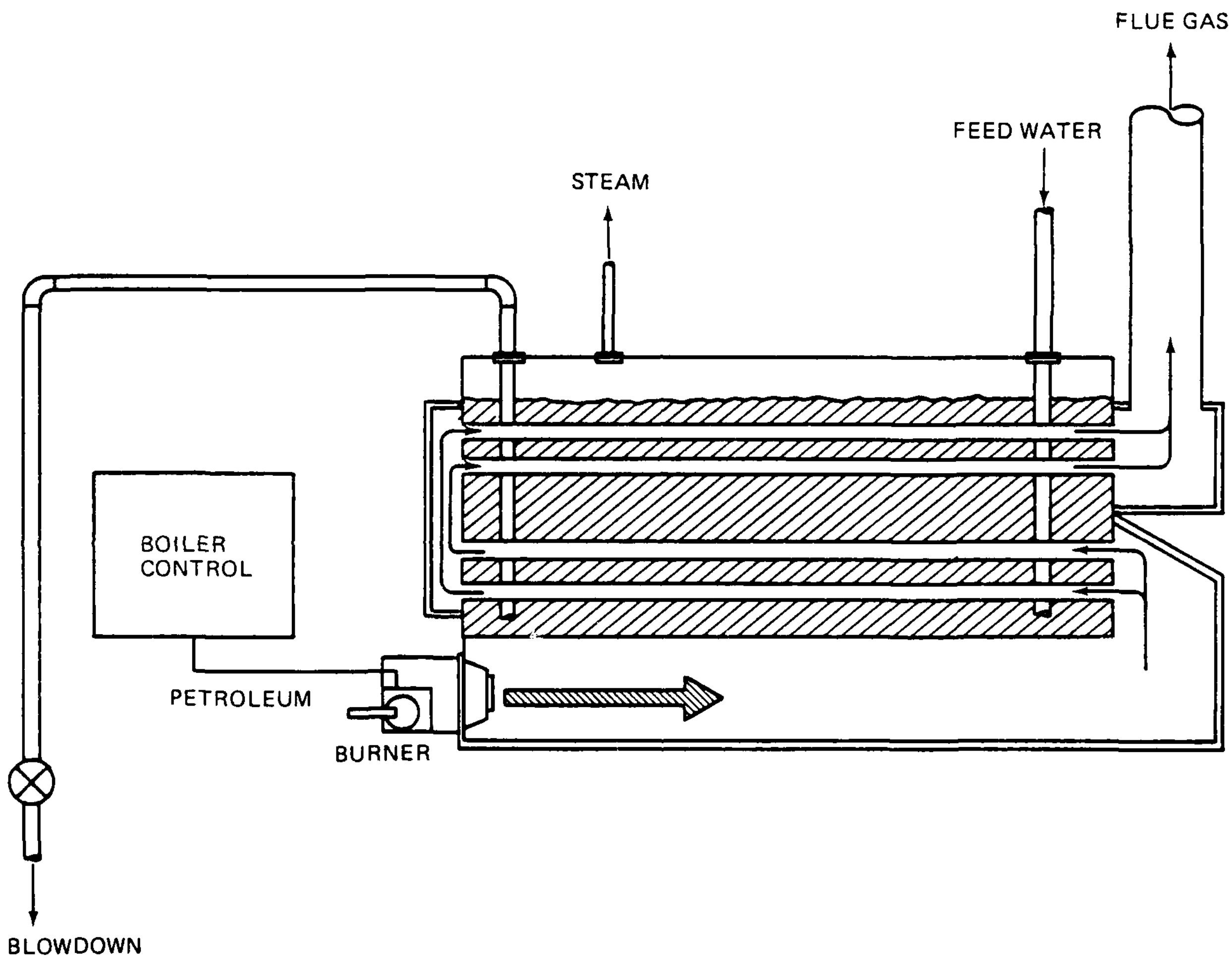


Figure HVAC-3. Replace Boiler Controls

HVAC 3. REPLACE BOILER CONTROLS

DESCRIPTION: On large boilers, complex central systems regulate the boiler operation and hence efficiency. Aging control systems subject to defective operation can waste energy. Automatic control systems can restore the system to proper operation. Some systems are designed to continuously adjust fuel/air mixtures to maintain minimum excess air for complete combustion in response to varying loads and environmental conditions. They can also be used to maintain various operating schedules and control auxiliary functions like blowdown control.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES	AGE OF BOILER CONTROLS (YEARS)
	10	15	

BENEFITS/DETRIMENTS: Modern control systems can be used to optimize boiler operation and control a variety of functions.

NEEDED SURVEY DATA:

- Boiler rated capacity (MBtu/hr)
- Annual hours of operation (hr/yr)
- Average operating load (% rated capacity)

PROCEDURE:

1. Fuel savings (MBtu/yr) = 0.05 x ((Avg Operating Load) x (Boiler Rated Capacity) x (operating hour/year))/(Boiler Efficiency)

GENERAL INFORMATION:

Sizes Available: 80×10^3 to 18×10^6 Btu/hr capacity
Startup Costs: \$580 to \$730 MBtu/hr capacity
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Mechanical contractor/electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Boiler size: 0.5 MBtu/hr
- 3,000 hr/yr
- 75% efficiency
- Average Load: 60% of rated capacity
- Startup Cost: \$370
- Change in O&M: \$20 (increase)
- Fuel Saved: No. 2 oil
- Energy Cost: \$5.12/MBtu
- Escalation Rate: 8%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

FUEL SAVINGS (MBtu/yr) =

0.05 x ((Avg Operating Load) x (Boiler Rated Capacity) x (Oper hr/yr)) x (1/Boiler Efficiency)

$$= \frac{0.05 \times 0.60 \times 0.5\ \text{MBtu/Hr} \times 3{,}000\ \text{hr/yr}}{0.75} = 60\ \text{MBtu/yr}$$

NES = 60 MBtu/yr

FUEL COST SAVINGS (\$/yr) =

= 60 MBtu/yr x \$5.12/MBtu = \$307

$$SIR = \frac{\$307\ (20.05) + (-\$20)\ (9.524)}{\$370\ (1.251)}$$

$$= 12.9$$

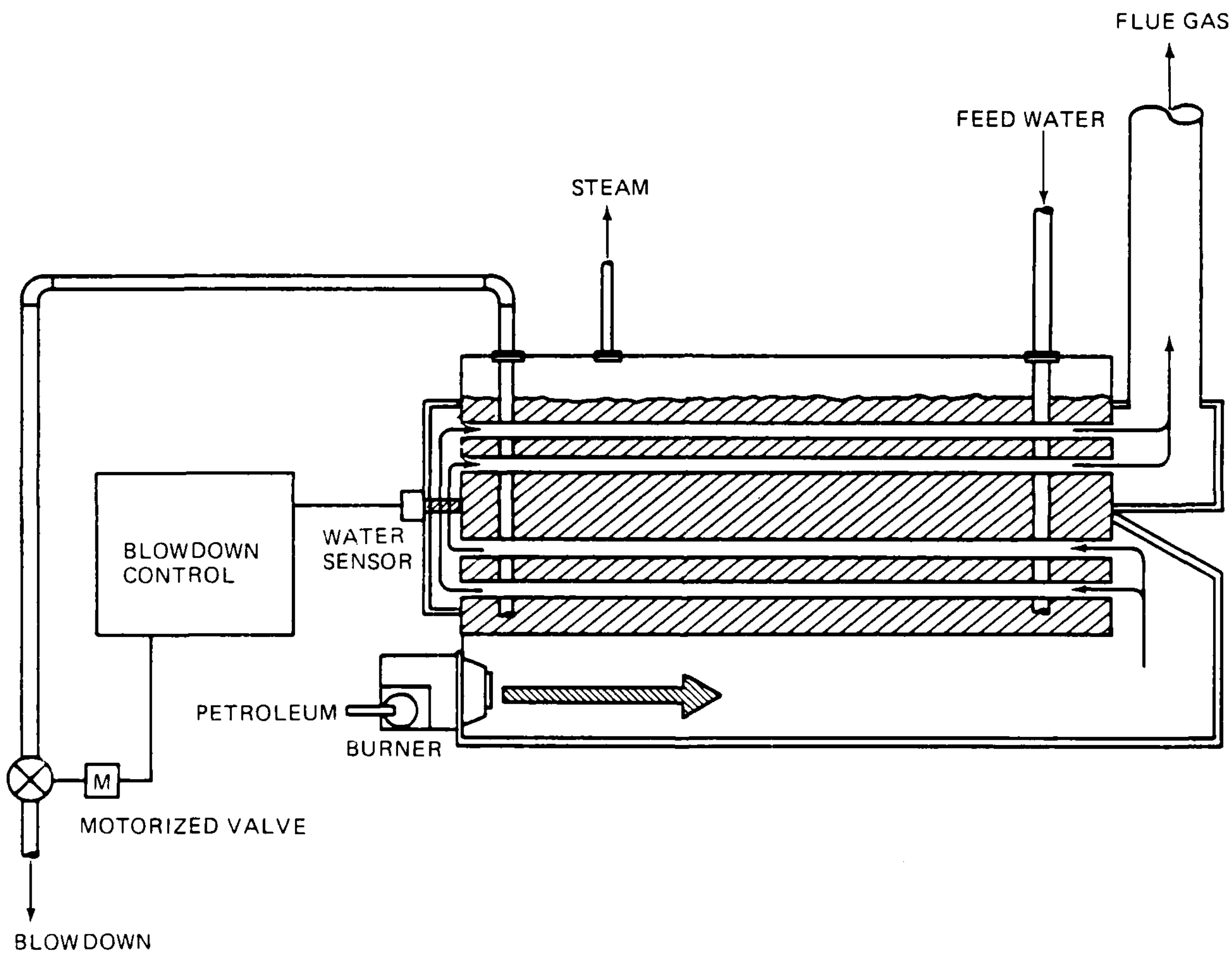


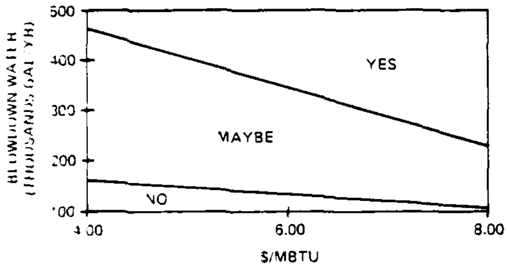
Figure HVAC-4. Install Automatic Blowdown Controls

HVAC 4. INSTALL AUTOMATIC BLOWDOWN CONTROLS

DESCRIPTION: Boiler blowdown is done to maintain a low concentration of dissolved and suspended solids in the boiler water and to remove sludge. Blowdown may be either manual, intermittent, or continuous.

The frequency of blowdown depends on the volume of solids in the boiler makeup water and the type of feed treatment used. Energy can be conserved by blowing down the boilers only when required. Automatic blowdown controls monitor boiler water conductivity and pH and initiate blowdown only as often as required to maintain acceptable water quality.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Automatic blowdown control can conserve energy while maintaining desired water quality.

SURVEY DATA NEEDS:

- Blowdowns/day
- Gallons/blowdown
- Boiler operating days/yr

PROCEDURE:

1. Determine the number of gallons of water discharged/blowdown.

2. Determine the annual energy consumed by boiler blowdown.

   Water Used = Blowdowns/day x gal/Blowdown x days/yr

   Energy Used = 1,300 Btu/gal* x Water Used (gal/yr)

3. Automatic control can save up to 20% of the energy used by limiting unnecessary blowdowns.

   Fuel Savings (MBtu/yr) = (0 to 20%)** x (Energy Used)

**Actual savings depend on local conditions.

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $3,000
Replacement Cost: Same as startup
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician, mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATIONS:

Assumptions:
1 blowdown/day, 365 days/yr, 50 gal/min flow rate, 30 sec duration, 15% energy savings
Startup Cost: $3,000
Change in O&M: None
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Water Used = (No. of Blowdowns/day) x (days/yr) x (Flow Rate) x (Duration)

$$= \left(\frac{1\ \text{Blowdown}}{\text{day}}\right) \times \left(\frac{365\ \text{days}}{\text{yr}}\right) \times \left(\frac{50\ \text{gal}}{\text{min}}\right) \times \left(\frac{0.5\ \text{min}}{\text{Blowdown}}\right)$$

= 9,125 gal/yr

Energy Used (MBtu/yr):

(1,300 Btu/gal) x (Water Used gal/yr) (MBtu/10^6 Btu) =

(1,300 Btu/gal) x (9,125 gal/yr) = 12 MBtu/yr

FUEL SAVINGS (MBtu/yr) =

(0.15***) x (12 MBtu/yr)

= 1.8 MBtu/yr

NES = 1.8 MBtu/yr

FUEL COST SAVINGS ($/yr) =

(1.8 MBtu/yr) x ($5.12/MBtu)

= $9.2/yr

$$SIR = \frac{\$9.2\ (20.05) - 0}{\$3,000\ (1.251)}$$

= 0.05

*(212°F - 55°F) x 1 Btu/lb °F x 8.3 lb/gal = 1,300 Btu/gal

***Assumed 15% savings in energy.

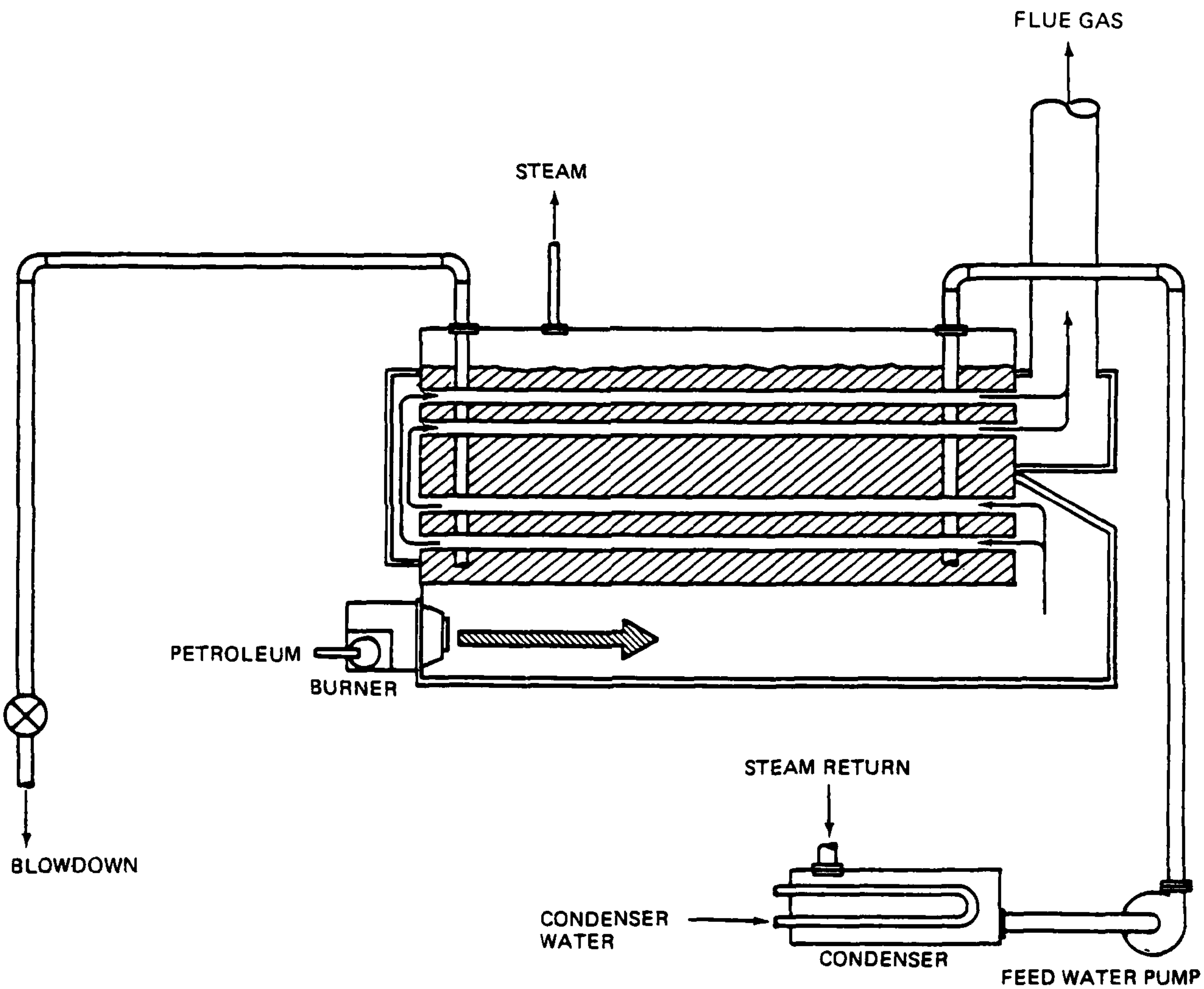
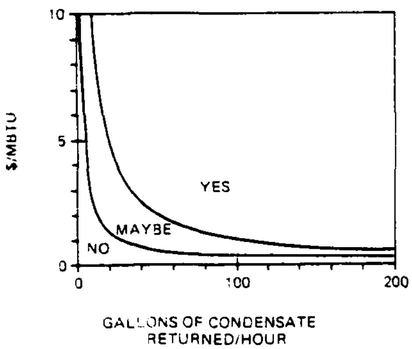


Figure HVAC-5. Return Steam Condensate to Boiler

HVAC 5. RETURN STEAM CONDENSATE TO BOILER

DESCRIPTION: Condensate is formed in steam distribution lines as steam loses its heat. Normally, the condensate is removed by means of steam traps to prevent "water hammer" and possible pipe damage, or to maintain steam quality (dryness). If the steam condensate is captured and returned to the boiler, it may either be used as boiler makeup water or used to preheat boiler makeup water thereby saving energy.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Benefits - water and energy are conserved. Detriments - cost of installing and maintaining the condensate lines.

SURVEY DATA NEEDS:

- Boiler rated capacity (MBtu/hr)
- Annual hours of operation (hr/yr)
- Condensate line installation and maintenance cost
- Required makeup water quantity
- Estimated percentage of generated steam that can be returned as condensate (gallons)
- Boiler efficiency
- Assume condensate system efficiency

PROCEDURE:

1. Determine the quantity of steam generated using actual load:

   Quantity of Steam Generated (lb/hr)

   $$\frac{\text{boiler rated capacity (Btu/hr) x (\% load)}}{\text{total heat of steam } (1.19 \times 10^3 \text{ Btu/lb})}$$

2. Determine heat energy available in condensate return as follows:

   Steam condensate return $\left[\frac{\text{gal of Condensate}}{\text{hr}}\right]$ =

   (Quantity of Steam Generated (lb/hr)) x (Condensate System Efficiency) x (1/8.3 lb/gal)

3. Determine fuel savings (MBtu/yr) as follows:

   (1,300 Btu/gal* x Cond Rtn'd (gal/hr) x

   Oper hr/yr)/Boiler Efficiency

* **Assuming condensate temperature is 212°F and makeup water temperature is 55°F, as follows: (212°F - 55°F) x 1 Btu/lb-°F x 8.3 lb/gal = 1,300 Btu/gal**

GENERAL INFORMATION:

Startup Cost: $50 per foot of pipe
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service Use	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E(\text{DERF}) + \Delta \text{O\&M (PYDF)}}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Boiler Rated Capacity: 2.4 MBtu/hr
Boiler Load: 2 MBtu/yr (80% of rated capacity)
Operating Hours: 8,760 hr/yr
Startup Cost: 300 ft condensate line @$50/ft = $15,000.00
Boiler Efficiency: 75%
Equipment Life: 15 years
Condensate System Efficiency: 70%
Change in O&M: $500/yr (increase)
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Quantity of Steam Generated} = \frac{\text{Boiler Rated Capacity x \% Load}}{\text{Total Heat of Steam}}$$

$$= \frac{2.4 \text{ MBtu/hr x } 0.80}{1.19 \times 10^3 \text{ Btu/lb}}$$

= 1,613.4 lb/hr

Potential Steam Condensate Return =

$$\frac{\text{Quantity of Steam Generated x Condensate System Efficiency}}{8.3 \text{ lb/gal}}$$

= (1,613.4 lb/hr x 0.70)(1/8.3 lb/gal)

= 136 gal of Cond Returned/hr

FUEL SAVINGS (MBtu/yr) =

(1,300 Btu/gal x 136 gal of Cond/hr x 8,760 Oper hr/yr) (MBtu/10^6 Btu)/0.75

= 2,066 MBtu/yr

HVAC 5. RETURN STEAM CONDENSATE TO BOILER - CONTINUED

NES (MBtu/yr) =

2,066 MBtu/yr

FUEL COST SAVINGS ($/yr) =

2,066 MBtu/yr x $5.12/MBtu

= $10,578/yr

SIR =

$$\frac{\$10,578\ (20.050) + 0 + (-\$500)\ (9.524)}{\$15,000\ (1.251)}$$

= 11.05

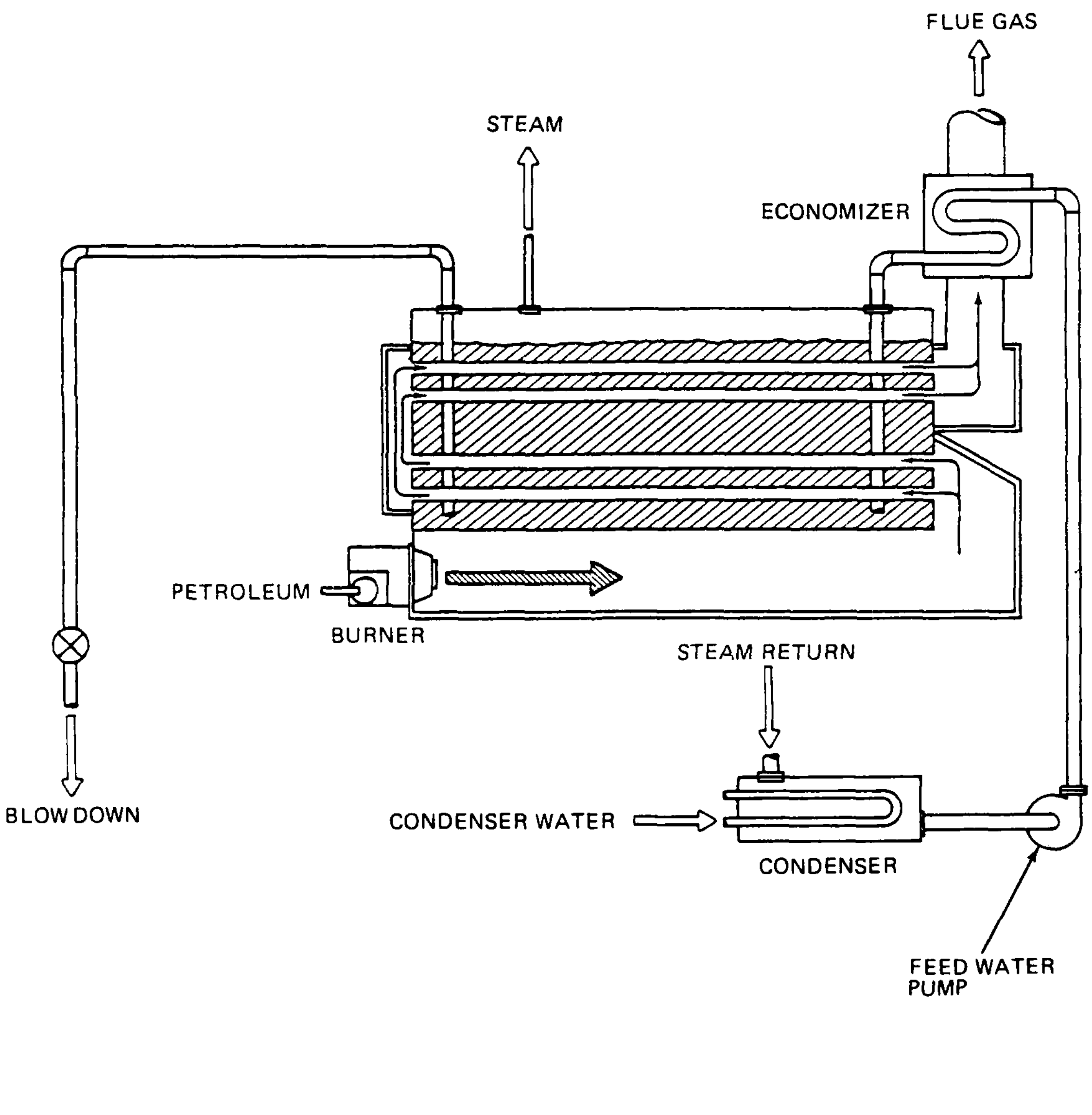
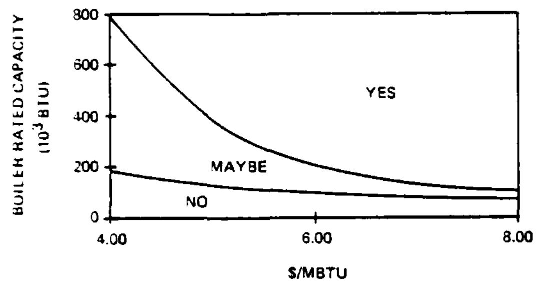


Figure HVAC-6. Preheat Boiler Feed Water

HVAC 6. PREHEAT BOILER FEED WATER

DESCRIPTION: Preheating boiler feed water before it enters the boiler using waste heat will reduce energy consumption. One source of waste heat that can be harnessed is the exiting flue gas. Care should be taken to prevent the stack temperature from falling below 350°F. At lower temperatures, acidic condensate may develop which is harmful to boiler equipment.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Fuel savings of greater than 10% can be obtained depending on feed water supply temperature and waste heat source.

SURVEY DATA NEEDS:

- Identify boilers without preheated feed water
- Boiler rated capacity (MBtu/hr)
- Average operating load (% rated capacity)
- Annual hours of operation
- Stack temperature (°F)

PROCEDURE:

1. Enter figure 1 (in figure section) at the existing stack temperature, and determine the percent fuel savings using an economizer for feed water preheat.
2. Fuel Savings (MBtu/yr) =

   % Fuel Savings x (Avg Boiler Load) x (Boiler Rated Capacity) x (Oper hr/yr) x (1/Boiler Efficiency)

GENERAL INFORMATION:

Sizes Available: N/A
Startup Costs: $1,760 to $2,200 MBtu/hr boiler capacity
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

Stack Gas Temperature (Existing): 550°F
0.5 MBtu/hr capacity, 3,000 hr/yr operation
Boiler Efficiency: 75%
Average Operating Load: 60% of rated capacity
Startup Cost: $1,100
Change in O&M: $60 (increase)
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Percent Fuel Saved:

	Stack Temp (°F)	Fuel Savings (%)
Existing	550	4

FUEL SAVINGS (MBtu/yr) =

(% Fuel Saving) x (Avg Boiler Load) x

(Boiler Rated Capacity) x (Oper Hr) x (1/Boiler Efficiency)

$$= \frac{0.04 \times 0.6 \times 0.5 \text{ MBtu/hr} \times 3{,}000 \text{ hr/yr}}{0.75}$$

= 48 MBtu/yr

NES = 48 MBtu/yr

FUEL COST SAVINGS ($/yr) =

48 MBtu/yr x $5.12/MBtu = $246/yr

$$SIR = \frac{\$246\ (20.05) + (-\$60)\ (9.524)}{\$1{,}100\ (1.00)}$$

= 3.96

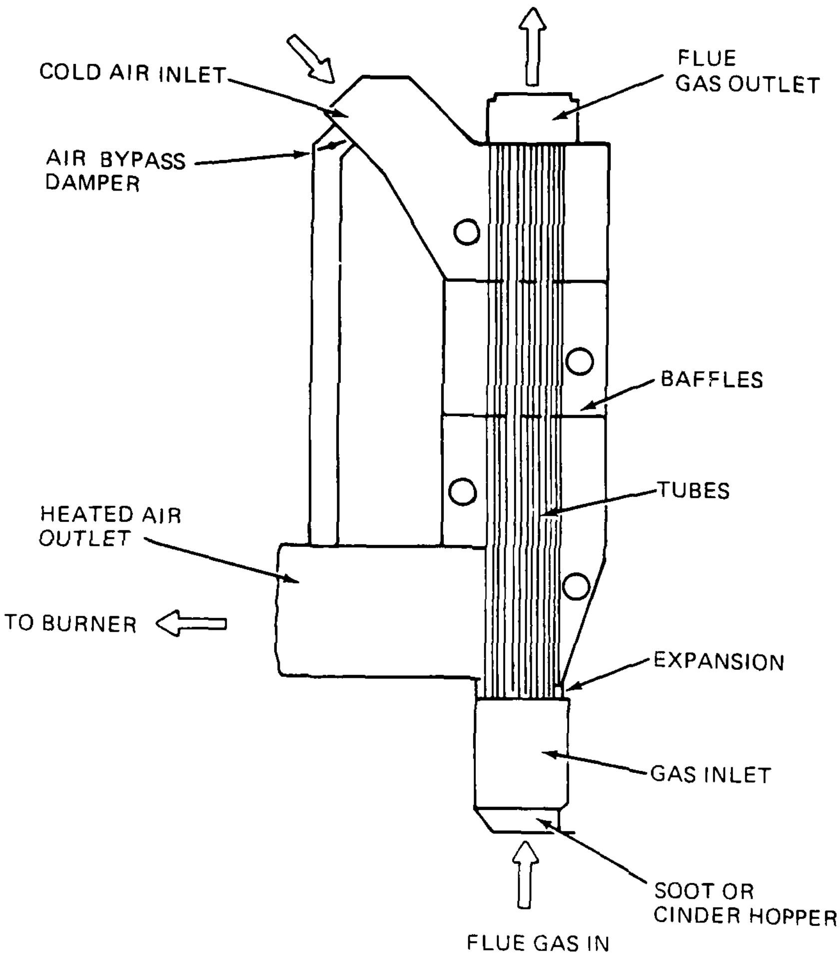


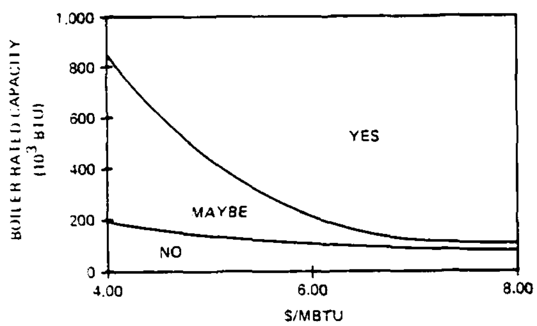
Figure HVAC-7. Preheat Combustion Air

HVAC 7. PREHEAT COMBUSTION AIR

DESCRIPTION: Preheating the air that is supplied to the combustion chamber reduces the amount of fuel required to raise the incoming air fuel mixture to the boiler operating temperature. The boiler manufacturer should be contacted to make sure that a preheater can be installed. Frequently preheating is accomplished with heat from the boiler flue gases.

Care should be taken to insure that the flue gas temperature does not drop below 350°F. At lower temperatures acidic condensate may develop which is harmful to the boiler equipment.

FEASIBILITY REQUIREMENT*:



*REQUIRES MINIMUM STACK TEMPERATURE OF 450°F

BENEFITS/DETRIMENTS: Fuel consumption can be cut by up to 10 percent.

SURVEY DATA NEEDS:

- Identify boilers without air preheating
- Boiler rated capacity (MBtu/hr)
- Annual operating hours (hr/yr)
- Boiler efficiency
- Avg operating load (% rated capacity)

PROCEDURE:

1. Air preheating using boiler flue gases may be practical if the stack temperature is above 450° F. For optimum savings and safety air may be heated to 600°F for pulverized fuels, 350°F for stoked coal, oil, and gas. Enter figure 2, (figures section) with the suggested combustion air temperature and find the percent efficiency increase.

2. Fuel Savings (MBtu/yr) =

   % Efficiency Increase x Avg Operating Load x Boiler Efficiency x Boiler Rated Capacity x Operating hr/yr

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $1,200 to $1,800 MBtu/hr boiler capacity
Replacement Cost: Same as startup costs
Equipment Life: 25 years
Skill Level of Personnel Required: Mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
0.5 MBtu/hr boiler capacity, 3,000 hr/yr operation, 79% efficiency
Average operating load: 60% of rated capacity, 500°F stack temperature
Startup Cost: $900
Change in O&M: $50 (increase)
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Percent Efficiency Increase: 6.5%

FUEL SAVINGS (MBtu/yr) =

% Efficiency Increase x Avg Operating Load x Boiler Efficiency x Boiler Rated Capacity x Operating hr/yr

= 0.065(0.60)(0.79)(0.5 MBtu/hr)(3,000 hr/yr)

= 46.2 MBtu/yr

NES = 46.2 MBtu/yr

FUEL COST SAVINGS ($/yr) =

46.2 MBtu/yr x $5.12/MBtu

= $237/yr

$$SIR = \frac{\$237\ (20.05) + (-\$50)\ (9.524)}{\$900\ (1)}$$

= 4.75

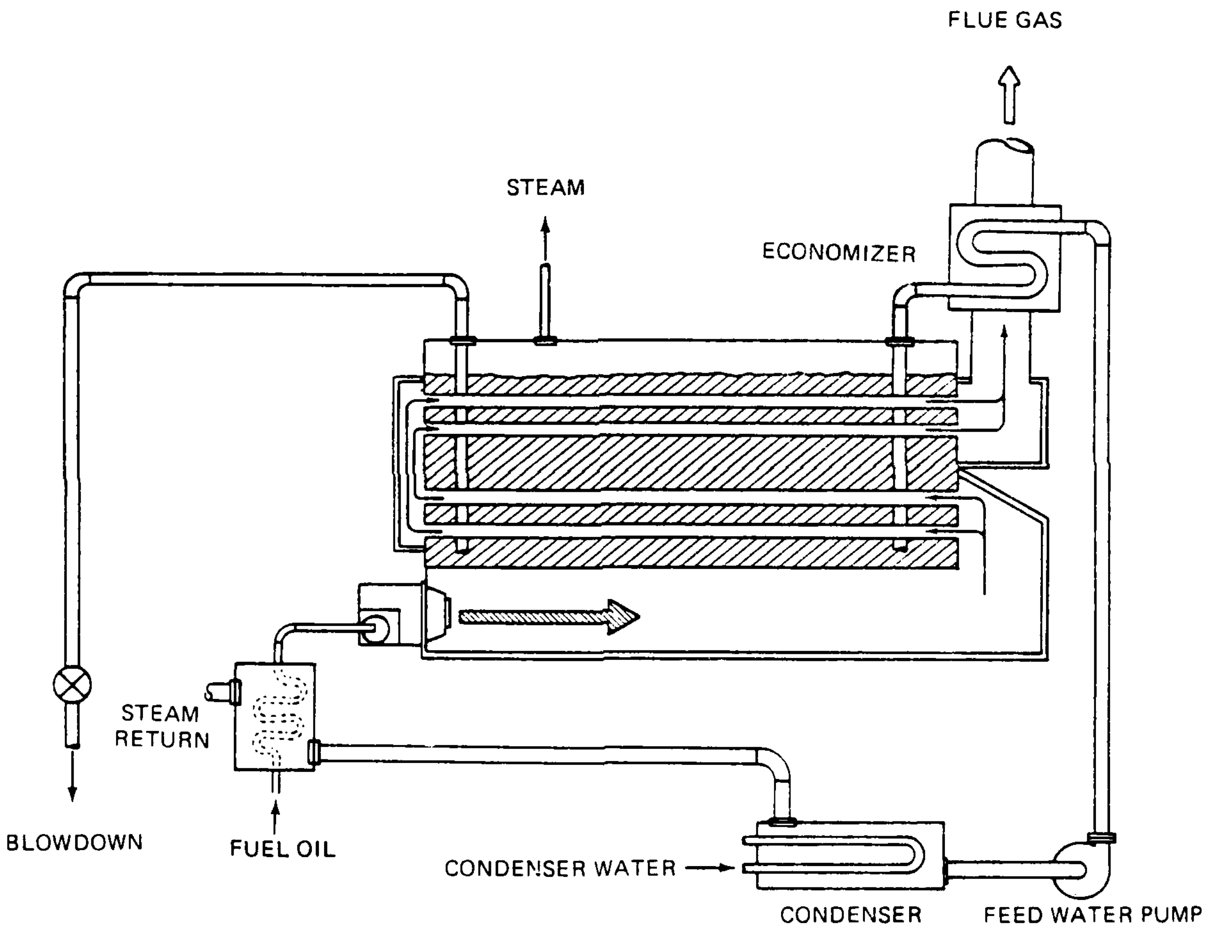


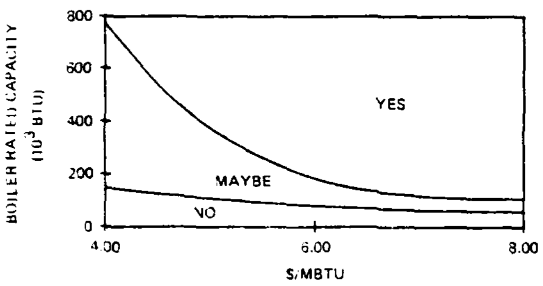
Figure HVAC-8. Preheat Fuel Oil

DESCRIPTION: Certain low sulfur oils require continuous heating to prevent the formation of wax deposits. Heavy oils must be preheated to the following temperatures to obtain complete atomization.

No. 4 oil - 135°F
No. 5 oil - 185°F
No. 6 oil - 210°F

Heating beyond these temperatures will increase efficiency but care must be taken not to overheat or vapor locks may form. Waste heat from flue gases, blowdown, condensate, or hot wells can be used.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Efficiency improvements of up to 3 percent can be obtained by preheating.

SURVEY DATA NEEDS:

- Determine boilers burning No. 4, 5, and 6 fuel oil
- Boiler rated capacity (MBtu/hr)
- Annual hours of operation
- Average operating load (% rated capacity)
- Boiler Efficiency

PROCEDURE:

1. Determine boiler annual energy consumption = Avg Boiler Load x Boiler Efficiency x Boiler Rated Capacity x Oper hr/yr

2. Fuel Savings (MBtu/yr) =

   0.03 x annual boiler energy consumption

GENERAL INFORMATION:

Sizes Available: N/A
Startup Costs: $1,200 to $1,800 MBtu/hr boiler capacity
Replacement Cost: Same as startup costs
Equipment Life: 25 years
Skill Level of Personnel Required: Mechanical contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C\ (PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Boiler Rated Capacity: 0.5 MBtu/hr
Hours of Operation: 3,000 hr/yr
Boiler Efficiency: 79%
Oil Preheat: 185°F
Avg Operating Load: 60% of rated capacity
Startup Cost: $750
Change in O&M: $50 (increase)
Fuel Saved: No. 5 oil
Energy Cost: $4.59/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Annual Energy Consumption =

Avg Boiler Load x Boiler Eff x Boiler Rated Capacity x Oper hr

= 0.60 (0.79) (0.5 MBtu/hr) (3,000 hr/yr) = 711 MBtu/yr

FUEL SAVINGS (MBtu/yr) =

0.03 (711 MBtu/yr) = 21.33 MBtu/yr

NES = 21.33 MBtu/yr

FUEL COST SAVINGS ($/yr) =

21.33 MBtu/yr ($4.59/MBtu) = $98/yr

$$SIR = \frac{\$98\ (20.05) + (-\$50)\ (9.524)}{\$750\ (1)}$$

$$= 1.98$$

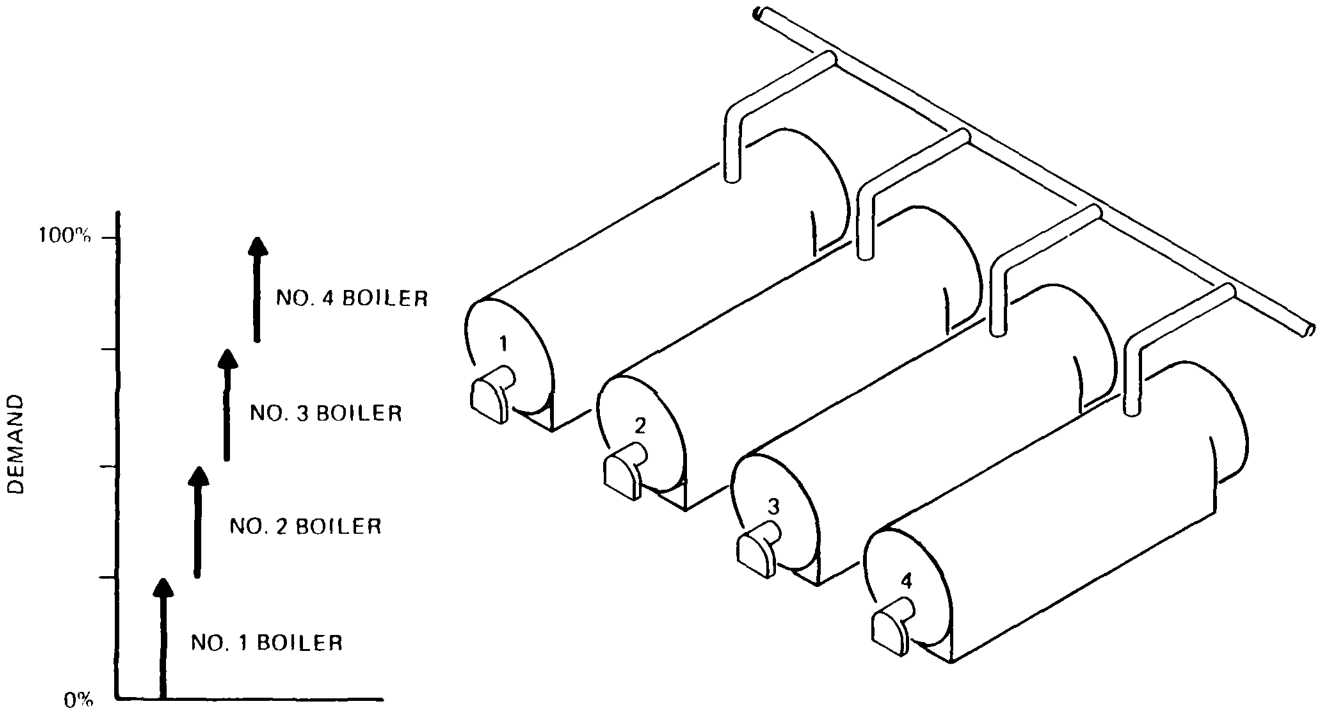


Figure HVAC-9. Replace Existing Boiler with Modular Boiler

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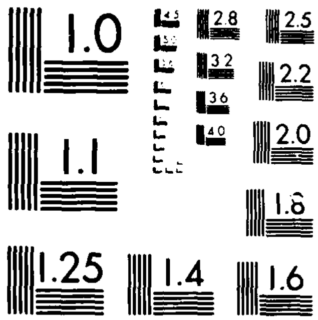


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

DESCRIPTION: Heating boilers are usually designed to operate at maximum efficiency when producing their rated output. Heating systems usually operate at loads of 60% capacity or less resulting in significant boiler inefficiencies. High-low firing rate burners can be installed to address the problem but are less effective than modular boilers.

In a modular boiler installation, a series of small capacity boilers that can be fired independently are used to meet the load. The boilers have small thermal inertias that allow rapid response and low heat up and cool down losses. As a building's load increases, boilers are brought on line in steps to more closely match the demand curve.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES
100% – 75%	75% – 60%	60% – 0%

AVERAGE PERCENTAGE OF FULL LOAD CAPACITY OF PRESENT BOILER

BENEFITS/DETRIMENTS: The use of modular boilers allow the building's heating plant to more closely match the demand curve while improving plant efficiency.

SURVEY DATA NEEDS:

- Boiler rated capacity
- Annual hours of operation (hr/yr)
- Boiler efficiencies vs percent capacity
- Boiler demand profile

PROCEDURE:

1. Using boiler operation logs, establish the number of hours of operation for boiler loads in 20% increments. For example, a typical boiler might operate at 100% capacity for 500 hours, at 80% capacity for 900 hours, etc.

2. Construct a graph (histograph) of operating hours vs percent full load (see figure 3 in figure section for example). Area under this graph represents total energy supplied by the boiler.

3. Determine percentage of total operating hours for each load increment.

4. Calculate efficiency of existing boiler using relative efficiency for various percent load capacities (i.e., demand) using figure 4 (in figures section) as follows:

$$E_{Total} = P_1E_1 + P_2E_2 + P_3E_3 + P_44E_4 + P_5E_5$$

where: E_{Total} = Boiler Efficiency
E = Relative Efficiency (figure 4)
P = Percent operating time

5. Determine the modular boiler capacities necessary to match the boiler demand curve, developed in steps 1 through 3. Contact manufacturers for available boiler capacities.

6. For each modular boiler selected, calculate the energy contribution for the modular boilers within each load increment as follows:

   % of total operating hours x ratio of steam supplied by the specific modular boiler to total demand (i.e. percent full load of existing boiler).

7. Calculate efficiency contribution of modular boilers using relative efficiency for various percent load capacities (i.e. demand) of modular boilers using figure 4 (in figure section) as follows:

$$E_{Mod\ Total} = P_1E_1 + P_2E_2 + P_3E_3 + P_4E_4 + P_5E_5$$

8. Combined relative efficiencies are calculated by summing over the modular efficiency contribution ($E_{Mod\ total\ 1} + E_{Mod\ total\ 2} + \ldots + E_{Mod\ total\ N}$)

9. Efficiency Improvement =

   Products (modular) - Products (existing)

10. Fuel Savings (MBtu/yr) =

   (Efficiency Improvement/100) x Annual Boiler Consumption

GENERAL INFORMATION:

Startup costs: (installed)	Gas	$ 4,300	to	$ 55,000
	Oil	6,700	to	55,000
	Coal	6,700	to	133,000
	Electric	15,000	to	32,000

Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Mechanical contractor, steam fitter
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in Btu/yr) x

11,600 Btu/kwh)

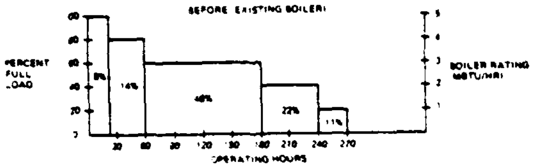
ECONOMIC ANALYSIS EQUATION:

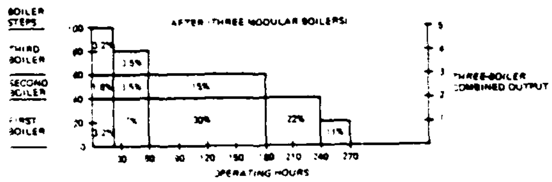
$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Average Boiler Load: 60% of rated capacity
Overall Boiler Efficiency: 79%
Replacement Boilers: Three Boiler Steps = 200×10^3, 100×10^3, 200×10^3 Btu/hr
Startup Cost: $8,370
Change in O&M: $420 (increase)
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:





*NOTE: Established one $1x10^5$Btu/hr and two $2x10^5$ Btu/hr boilers as new equipment.

Relative Efficiency of Existing Boiler

E = Relative efficiency
P = Percent operating time

$P_1 E_1 + P_2 E_2 + P_3 E_3 + P_4 E_4 + P_5 E_5 =$

0.08(1) + 0.14(0.93) + 0.45(0.875) + 0.22(0.85) +

0.11(0.82) = 0.88

Combined Relative Efficiency

First Boiler: Efficiency contribution

$\overset{(1)}{0.032} + \overset{(1)}{0.07} + \overset{(1)}{0.30} + \overset{(1)}{0.22} + 0.11(0.86) = 0.7166$

Second Boiler: Efficiency contribution

$\overset{(1)}{0.016} + \overset{(1)}{0.035} + \overset{(1)}{0.15} = 0.201$

Third Boiler: Efficiency contribution

$\overset{(1)}{0.032} + 0.035(0.86) = 0.0621$

Three-Boiler Combined Efficiency:

0.716 + 0.201 + 0.062 = 0.98

INCREASE IN RELATIVE EFFICIENCY =

New Relative Efficiency - Old Relative Efficiency

= 98% - 88% = 10%

ENERGY CONSUMPTION (MBtu/yr) =

Average Boiler Load x Overall Boiler Efficiency x

Boiler Rated Capacity x Operating hr/yr

= 0.60 x 0.79 x 0.5 MBtu/hr x 3,000 hr/yr

= 711 MBtu/yr

FUEL SAVINGS (MBtu/yr) =

Efficiency Increase x Annual Energy Consumption

= 0.10 (1,139 MBtu/yr) = 71.1 MBtu/yr

NES = 71.1 MBtu/yr

FUEL COST SAVINGS ($/yr) =

71.1 MBtu/yr x $5.12/MBtu = $364/yr

$$SIR = \frac{\$364\ (20.05) + (-\$420)\ (9.524)}{\$8,370\ (1.0)}$$

= 0.40

Although the retrofit SIR is very low, if the existing boiler replacement is required, a modular boiler should be considered. In this case, ΔC would replace C.

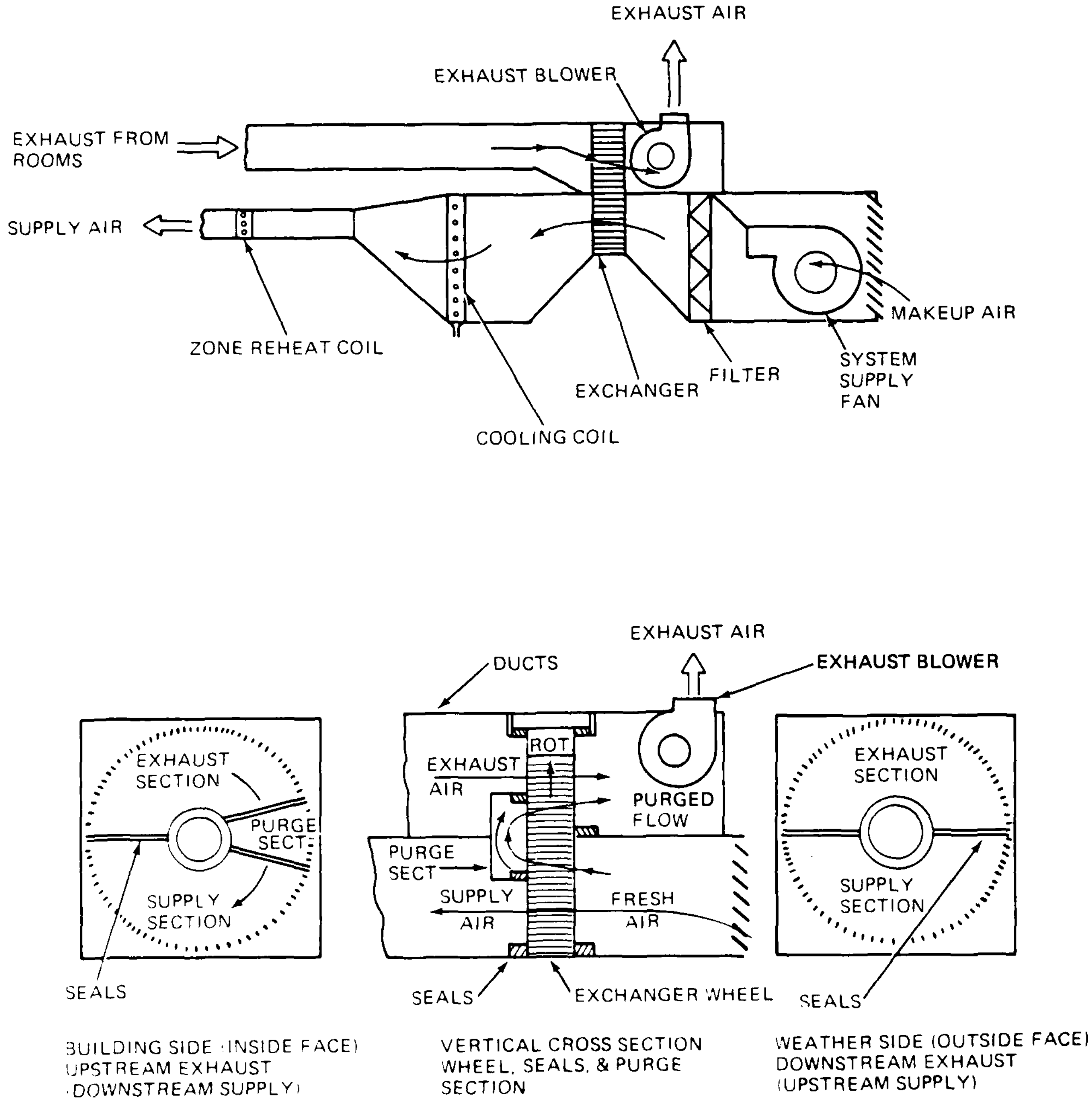


Figure HVAC-10. Install Heat Recovery Equipment

SAMPLE CALCULATION:

Assumptions:
10,000 cfm HVAC equipment, 4,000 heating degree days, 5,000 annual dry bulb degree hours above 78°F, heating plant efficiency (HEFF) = 0.75, EER = 6.8 (cost)
Startup Cost: $14,800
Change in O&M: $300 (increase)
Fuel Saved: No. 2 oil, electricity
Energy Cost: $5.12/MBtu, $0.08/kwh
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

FUEL SAVINGS (MBtu/yr) =

$$\frac{\text{cfm (exhaust)} \times \text{Heating degree days} \times 18.44}{\text{Heating Plant Efficiency}} \times$$

(MBtu/10^6 Btu)

$$= \frac{10{,}000 \times 4{,}000 \times 18.44}{0.75}\left(\frac{\text{MBtu}}{10^6\ \text{Btu}}\right) = 983\ \text{MBtu/yr}$$

ELECTRICAL SAVINGS (kwh/yr) =

$$\frac{\text{cfm} \times \text{Dry bulb degree hours} \times 0.756}{6.8} \times \frac{\text{kwh}}{1{,}000\ \text{wh}}$$

$$= \frac{10{,}000 \times 5{,}000 \times 0.756}{6.8 \times 10^3} = 5{,}560\ \text{kwh/yr}$$

NES =

983 MBtu/yr + (5,558.8 kwh/yr x 11,600 Btu/kwh) x

MBtu/10^6Btu = 1,050 MBtu/yr

FUEL COST SAVINGS ($/yr) =

983 MBtu/yr ($5.12/MBtu) = $5,033/yr

ELECTRICAL COST SAVINGS ($/yr) =

5,560 kwh/yr x $0.08/kwh = $445/yr

SIR =

$$\frac{\$5{,}033\ (20.05) + \$445\ (18.049) + (-\$300)\ (9.524)}{\$14{,}800\ (1.00)}$$

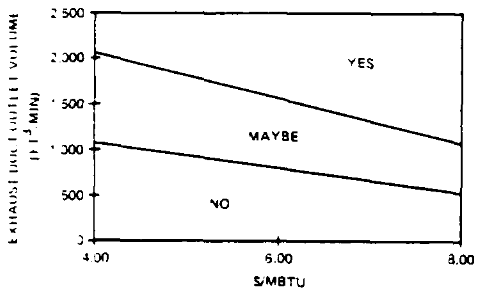
= 7.17

HVAC 10. INSTALL HEAT RECOVERY EQUIPMENT

DESCRIPTION: A wide variety of heat recovery equipment is available for use. A typical installation is shown in Figure HVAC 10. In facilities where large amounts of conditioned air is exhausted, rotary heat recovery wheels can be installed to transfer energy to the incoming makeup air. These wheels consist of a porous fiber or ceramic disk placed in the air stream. Hot exhaust air passes through the disk which absorbs its heat. The disk rotates so that the heated section then passes across the cool incoming air stream which absorbs heat from the disk.

Air-to-air heat exchangers can be used to transfer heat from one air stream to another by direct contact on either side of a metal heat transfer surface. Heat pipes can also be employed to transfer heat efficiently. Various other types of heat exchangers like the shell and tube heat exchanger can be used to recover heat from fluids such as hot condensate, refrigerant, and blowdown water.

FEASIBILITY REQUIREMENT:



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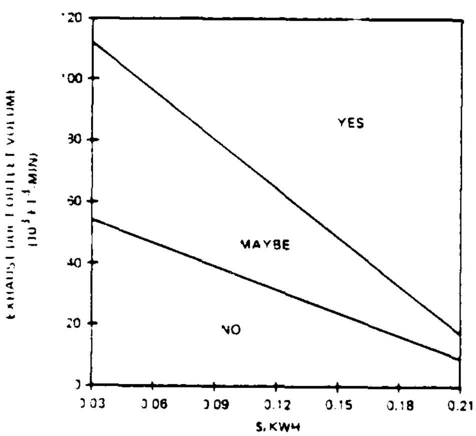


BENEFITS/DETRIMENTS: The harnessing of waste heat where practical is an excellent conservation opportunity. Energy otherwise discarded can be utilized to perform a needed function. Additional maintenance of equipment may be required and should be evaluated on an individual basis.

SURVEY DATA NEEDS:

- Temperature of exhaust air stream (°F)
- Flowrate of exhaust air (cfm)
- Temperature of makeup air (°F)
- Flowrate of makeup air (cfm)
- Heating degree days
- Dry bulb degree hours above 78°F
- Annual operating hours (hr/yr)
- Heating Plant Efficiency (HEFF)
- Cooling Energy Efficiency Ratio (EER)

PROCEDURE:

1. Determine the temperature and flowrate of exhaust and makeup air streams.

2. For sensible heat recovery:

   Fuel Savings (MBtu/yr) =

$$\frac{\text{cfm (exhaust)} \times \text{Heating degree days} \times 18.144^*}{\text{Heating Plant Efficiency}} \times (\text{MBtu}/10^6\text{Btu})$$

   Electrical Savings kwh/yr =

$$\frac{\text{cfm (out)} \times \text{Dry bulb degree hours} \times 0.756^*}{\text{EER}} \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

   *Derivation of Multipliers:

$$\frac{0.756\ \text{Btu}}{\text{cfm-}^{\circ}\text{F-Hr}} \times \frac{24\ \text{hr}}{\text{day}} = \frac{18.144\ \text{Btu}}{\text{cfm-}^{\circ}\text{F-day}}$$

$$1.08\ \frac{\text{Btu}}{\text{cfm-}^{\circ}\text{F-hr}} \times 0.70\ \text{Typical Heat Trans Efficiency} = \frac{0.756\ \text{Btu}}{\text{cfm-}^{\circ}\text{F-hr}}$$

3. For sensible heat recovery where the duct inlet and outlet temperatures are not equal to outdoor and indoor temperature, the savings may be calculated using the following equation:

   Fuel Savings (MBtu/yr) = cfm (exhaust) x (T Exh - T Makeup) x 0.756* x Operating hr/yr x MBtu/10⁶Btu

GENERAL INFORMATION:

Sizes Available: 1,700 to 41,000 cfm
Startup Costs: $3,000 to $39,500
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Sheetmetal worker
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in Btu/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(\text{DERF}) + \Delta E_{elec}(\text{DERF}) + \Delta\text{O\&M}\ (\text{PYDF})}{\text{C(PIF)}}$$

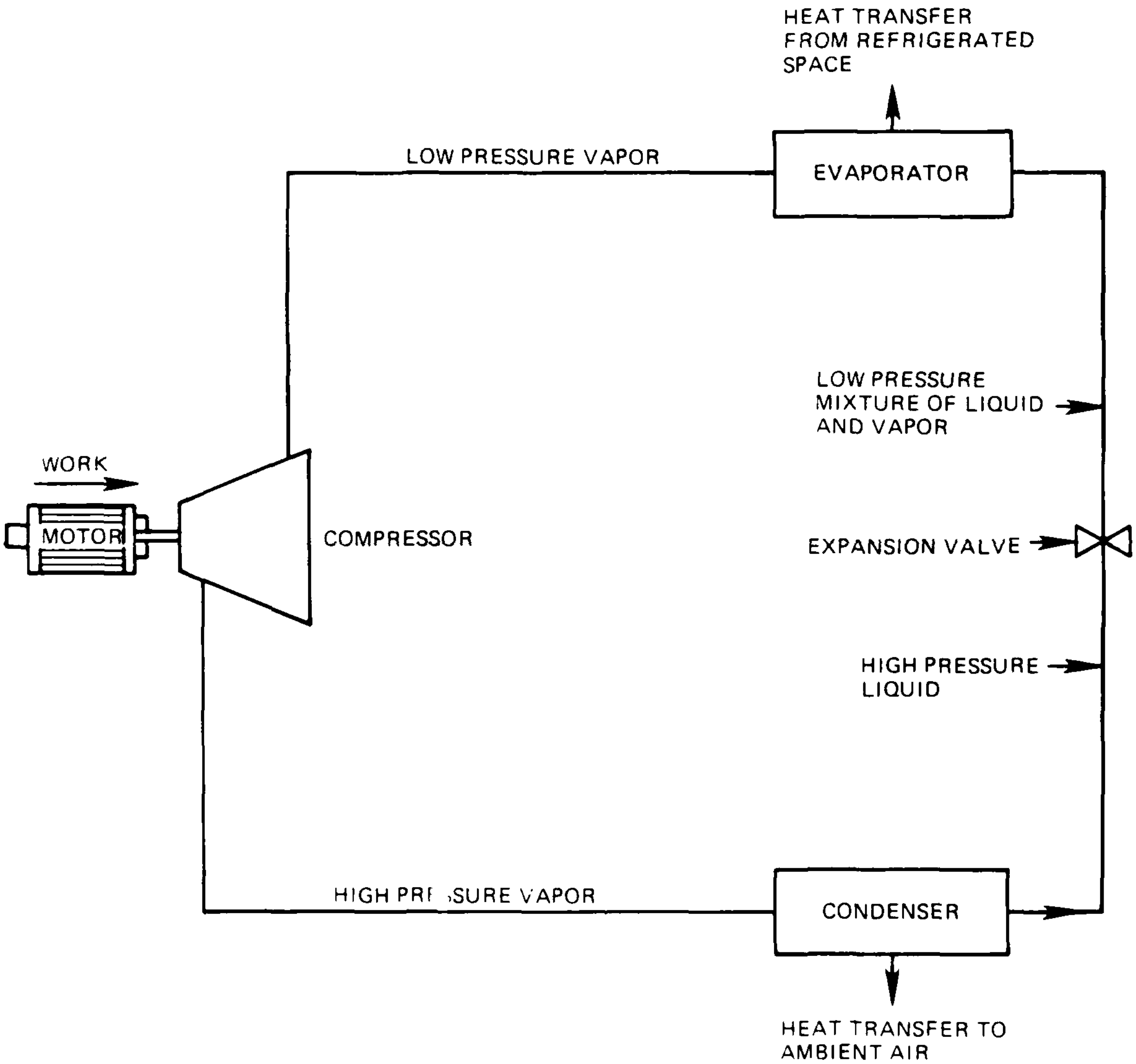


Figure HVAC-11. Replace Inefficient Air Conditioner Units

DESCRIPTION: Air conditioner units use the standard electrically driven vapor compression cycle. In recent times, great improvements in unit efficiencies have been made. In the industry, unit efficiencies are compared by the Energy Efficiency Ratio (EER) defined as:

$$EER = \frac{\text{Cooling Capacity (Btu/hr)}}{\text{Input Wattage (watts)}}$$

The input wattage for single-phase units =

Amps x Volts x Power Factor

The input wattage for three-phase units =

Total Amps x Volts x Power Factor x 1.73

The higher the value of the EER, the more efficient the air conditioner.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES

70 200

OPERATING HOURS PER YEAR BASED ON EER INCREASE OF 1.5.

BENEFITS/DETRIMENTS: Replacement of air conditioner with more efficient units can reduce energy consumption by 23%.

SURVEY DATA NEEDS:

- Energy efficiency ratio (EER) (existing and new)
- Cooling capacity (Btu/hr)
- Annual operating hours (hr/yr)

PROCEDURES:

1. Electrical Savings (kwh/yr) =

Cooling capacity (Btu/hr) x Operating hr/yr x

$$\left[\frac{1}{\text{EER (existing)}} - \frac{1}{\text{EER (new)}}\right] \times \frac{1\ \text{kwh}}{1{,}000\ \text{wh}}$$

GENERAL INFORMATION:

Sizes Available: 5,900 Btu/hr
12,000 Btu/hr
29,000 Btu/hr
Startup Costs: $505 (5,900 Btu/hr)
$747 (12,000 Btu/hr)
$1,208 (29,000 Btu/hr)
Replacement Cost: Same as startup cost
Equipment Life: 10 years
Skill Level of Personnel Required: Maintenance staff
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

Electrical Energy Savings (in kwh/yr) x

(11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
5 Units - 12,000 Btu/hr each, 500 hr/yr operation, EER (existing) 5, EER (new) 7
Startup Cost: $3,735
Change in O&M: No change
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

$$\text{Cooling Capacity} \times \text{Oper hr} \times \frac{\text{kwh}}{1{,}000\ \text{watts}} \times \left[\frac{1}{\text{EER (old)}} - \frac{1}{\text{(EER (new)}}\right]$$

$$= \frac{60{,}000\ \text{Btu}}{\text{hr}} \times \frac{500\ \text{hr}}{\text{yr}} \times \frac{\text{kwh}}{1{,}000\ \text{watts}} \times \left[\frac{1}{5\ \text{Btu/wh}} - \frac{1}{7\ \text{Btu/wh}}\right] = 1{,}714\ \text{kwh/yr}$$

NES (MBtu/yr) =

1,714 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu

= 20 MBtu/yr

FUEL COST SAVINGS ($/yr) =

1,714.3 kwh/yr x $0.08/kwh = $137/yr

$$SIR = \frac{\$137\ (18.049)}{\$3{,}735\ (1.561)}$$

$$= 0.424$$

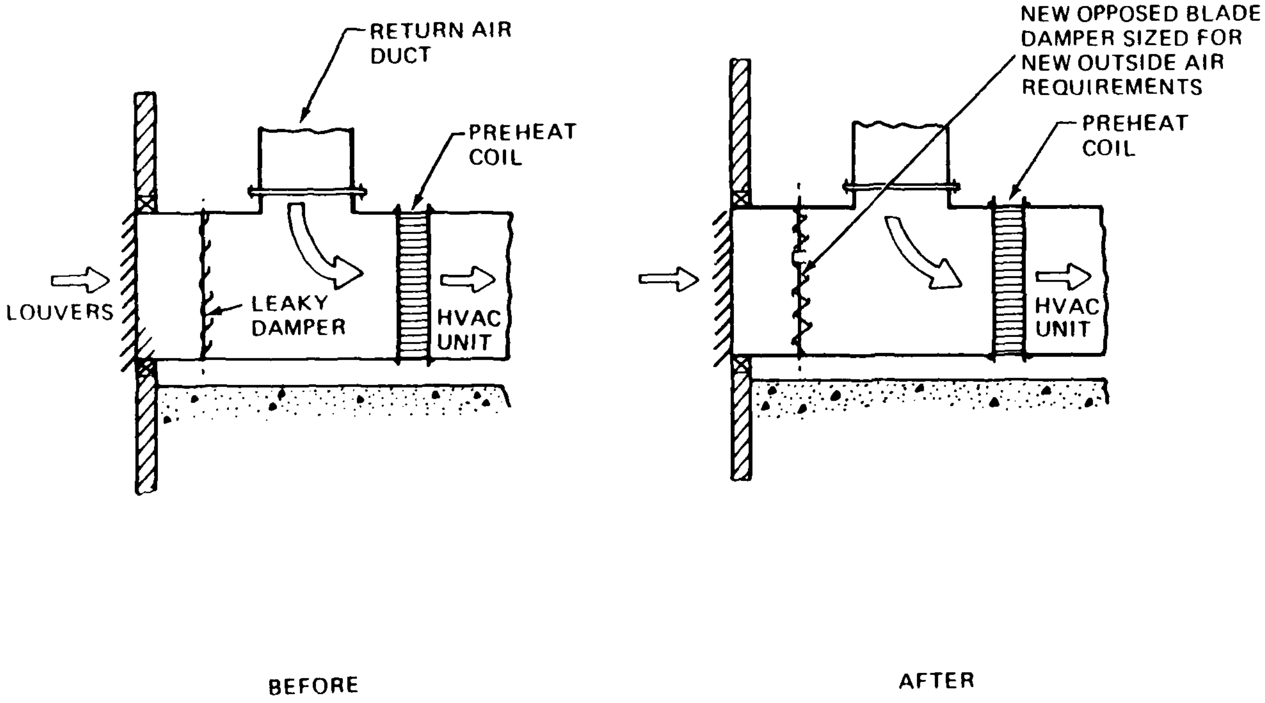
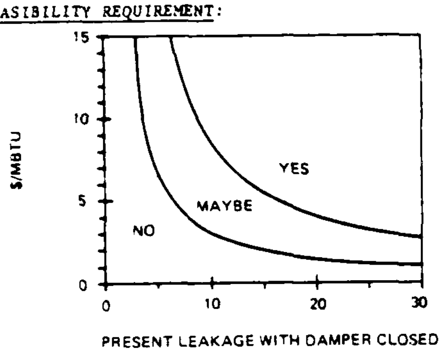


Figure HVAC-12. Install Low Leakage Dampers

DESCRIPTION: Leaking dampers in HVAC systems result in energy loss by allowing conditioned air to be exhausted or diluted unintentionally with outside air. This typically occurs during periods when outside air dampers are closed and only minimum outside air is to be introduced, as in the case during the morning warmup period. Standard dampers can allow from 5 to 30% leakage when closed. Low leakage dampers restrict leakage to 1%. Cooling savings potential is presumed negligible.

FEASIBILITY REQUIREMENT:



*SEE PROCEDURE STEP 1

BENEFITS/DETRIMENTS: Low leakage dampers conserve energy by restricting the amount of unwanted outside air.

SURVEY DATA NEEDS:

- Identify leakage for existing dampers
- Air handling unit capacity (cfm)
- Heating degree days
- Percent time fan runs during unoccupied hours
- Heating Energy Index (EIH)(MBtu)
- Heating Plant Efficiency (HEFF)

PROCEDURE:

1. Determine air handling unit capacity (cfm). Using following procedure, determine the existing damper leakage:

   With damper closed, measure outside air temperature (T_{os}), return air temperature (T_{rtn}), and temperature of mixed air into air handling unit (T_{mix}). The present leakage (in % of air handling unit cfm capacity) =

   $$\left[(T_{rtn} - T_{mix})/(T_{rtn} - T_{os})\right] \times 100\%.$$

2. Obtain heating energy index (EIH) from table SD2 (Supporting Data) for your location.

3. Fuel Savings (MBtu/yr) =

   (Unit ft^3/min/1,000 ft^3/min) x ((Existing Damper

   Leakage % -1%)/100%) x Heating Energy Index x

   (Unoccupied Fan Run hours per week/50 hr/wk) x

   (1/Heating Plant Efficiency)

GENERAL INFORMATION:

Sizes Available: 12 x 12 in. Damper - $100
60 x 42 in. Damper - $500
Startup Cost: Damper cost plus installation labor
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Sheetmetal worker

Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Air Handling Unit Capacity: 12,000 ft^3/min
Heating Plant Efficiency (HEFF) = 75%
Startup Cost: $750
Fan Run Time (unoccupied period): 1.75 hours per day x 5 days per week
Heating Energy Index (EIH) = 45 MBtu
T_{os} = 35°F; T_{rtn} = 68°F; T_{mix} = 65°F
Change in O&M: None
Fuel Saved: No. 2 oil
Energy Cost: $5.12/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Present damper leakage:

(68 - 65)/(68 - 38) x 100 = 10%

FUEL SAVINGS (MBtu/yr) =

(12,000/1,000) x ((10 - 1)/100) x 45 x

((1.75 x 5)/50) x (0.75) = 11.34 MBtu

NES (MBtu/yr) =

11.34 MBtu/yr

FUEL COST SAVINGS ($/yr) =

11.34 MBtu/yr x $5.12/MBtu = $58.06/yr

$$SIR = \frac{\$58.06\ (20.05) + 0 + 0}{\$750\ (1.251)}$$

= 1.24

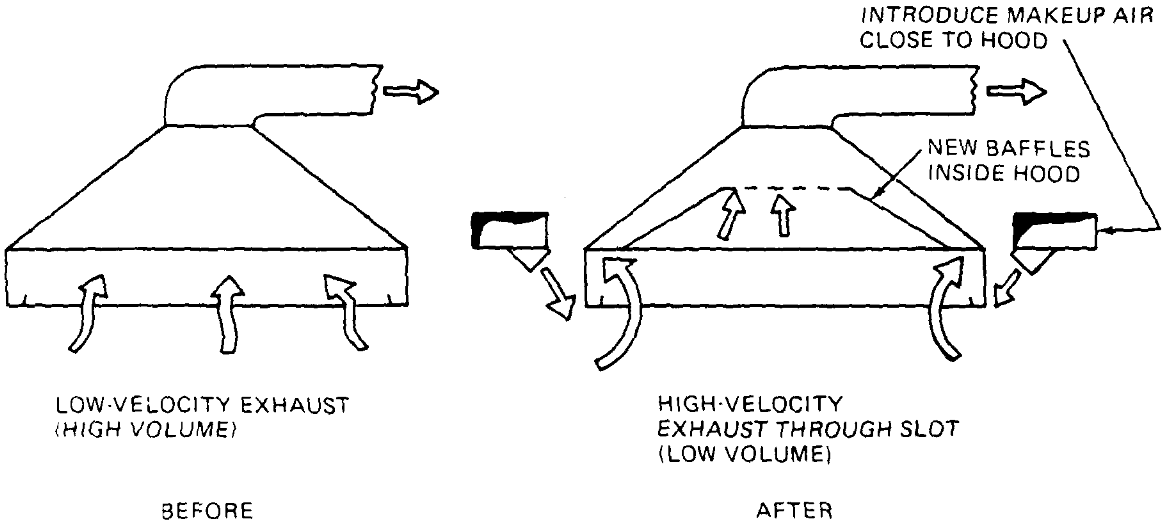
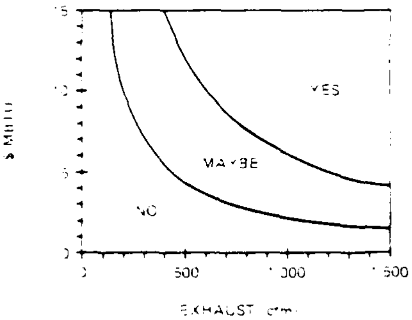


Figure HVAC-13. Provide Separate Makeup Air for Exhaust Hoods

DESCRIPTION: Exhaust hoods remove significant quantities of air from the buildings. Typically this makeup air is through the HVAC system which warms it in the winter and cools it in the summer. If the air extracted by the hoods can be drawn from an inlet nearby, the makeup air need not be conditioned to the same degree as space air. During the winter, air at 50°F to 55°F can be used at kitchen exhaust hoods without discomfort because of appliance heat output.

The effectiveness of an exhaust hood in capturing heated air, smoke, and fumes is a function of the face velocity at the edge of the hood. The face velocities of large hoods can be maintained while reducing the exhausted volume of air by installing baffles and false hoods within the existing hood (see figure HVAC 13).

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: The use of separate air intakes located near exhaust hoods conserves energy by reducing the volume of conditioned air exhausted from the building.

SURVEY DATA NEEDS:

- Makeup air temperature (°F)
- Volume of air exhausted by hood (cfm)
- Typical indoor temperature
- Heating degree days
- Hours of hood operation per week
- Heating Plant Efficiency (HEFF)

PROCEDURE:

1. Obtain flow rate of air exhausted by hood (in cfm). Use nameplate data and/or manufacturers' rating value. Domestic range hoods are typically [illegible] to 250 ft^3/min; commercial hoods are available in a very wide range, with 1,000 ft^3/min being typical.

2. Use nomograph 15 to determine the annual heat content in MBtu's per 1,000 ft^3/min of air exhausted. Note: Nomograph Hours of Occupancy Per Week refers to hours of hood operation per week.

3. Again using nomograph 15 this time using temperature of makeup air vice indoor air temperature, determine the annual energy in MBtu's needed to heat the makeup air.

4. Calculate annual fuel savings in MBtu's/yr as follows:

$$\frac{\text{Energy from Step 2} - \text{Energy from Step 3}}{\text{Heating Plant Efficiency}} \times$$

$$\frac{\text{Hood Exhaust cfm}}{1,000 \text{ cfm}} \times \text{MBtu}/10^6\text{Btu}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Costs: \$3.00/ft - duct work
\$18/ft - Diffuser
\$0.50 to \$1.00 cfm - fan
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Sheetmetal workers
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E(DERF) + \Delta O\&M (PYDF)}{C(PIF)}$$

SAMPLE CALCULATIONS:

Assumptions:
Hood Exhaust: 1,000 cfm
Hours of Operation Per Week: 80
Indoor Air Temperature: 68°F
Temperature of Makeup Air: 53°F
Heating Degree Days: 6,000
Heating Plant Efficiency (HEFF): 75%
Startup Cost: \$1,200
Change in O&M: None
Fuel Saved: No. 2 oil
Energy Cost: \$5.12 MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Volume of Air Exhausted (from hood nameplate) = 1,000 ft^3 min

Annual Energy Exhausted Per 1,000 ft^3 min (using nomograph 15, 6,000 degree days, 68°F, and 80 hours per week) = 75 x 10^6Btu/yr

Annual Energy Needed Per 1,000 ft^3/min for Heating the Makeup Air (using nomograph this time at 53°F) = 60 x 10^6Btu/yr

FUEL SAVINGS (MBtu/yr) =

$$\frac{75 \times 10^6 \text{ Btu/yr} - 60 \times 10^6 \text{ Btu/yr}}{0.75} \times \frac{1,000 \text{ ft}^3/\text{min}}{1,000 \text{ ft}^3/\text{min}}$$

$$\times \frac{\text{MBtu}}{10^6 \text{ Btu}} = 20 \text{ MBtu/yr}$$

NES (MBtu/yr) = 20 MBtu/yr

FUEL COST SAVINGS (\$/yr) =

20 MBtu x \$5.12 MBtu = \$102

SIR = [illegible]

= [illegible]

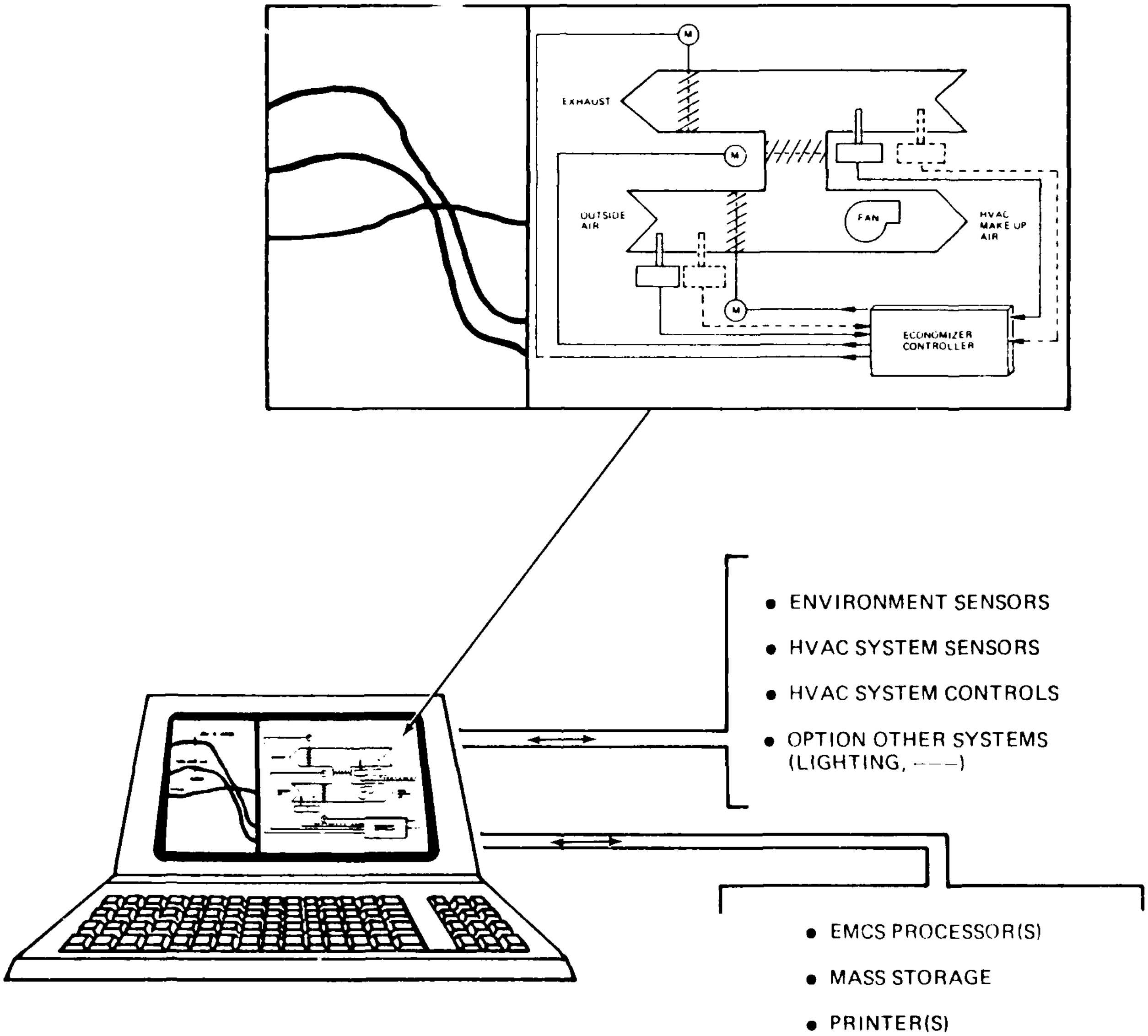


Figure HVAC-14. Energy Management and Control Systems Overview

HVAC 14. ENERGY MANAGEMENT AND CONTROL SYSTEMS OVERVIEW

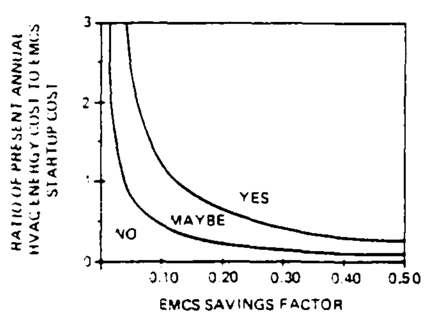
DESCRIPTION: Energy Management and Control Systems (EMCSs) are central microprocessor-based systems which exercise control over some or all of a building's (or group of buildings') major energy consuming systems such as HVAC and lighting. This overview addresses EMCS application (only). EMCSs offer a number of benefits. Since they are microprocessor-based systems, they are programmable, and thus can provide a very high degree of flexibility, both with respect to control strategies for energy waste avoidance, and for accommodating building use and occupancy schedule changes.

Various HVAC energy conserving control strategies are described in the ECOs that follow (HVAC 15 through HVAC 21). An EMCS contributes to energy conservation by employing and integrating such strategies (and possibly others as well). It is through effective integration of the various control strategies that energy savings over and above that achievable by the individual control strategies alone is often possible. These additional savings result from the EMCSs taking into account many more considerations in the exercise of control over the systems that it controls or supervises than would otherwise be possible. By being able to employ more complex algorithms, it is able to optimize the individual strategies to operate with each other, eliminating possible conflicts between them.

Another important benefit provided by a central EMCS is the ease and flexibility with which building occupancy and usage schedule changes (both temporary and long term) are accommodated. This is important since effective total energy management must necessarily take occupancy and usage schedules into account. An EMCS is also able to monitor itself and the systems it controls, and to collect and analyze data. This directly supports improved maintenance which translates to additional energy waste avoidance.

EMCSs are available in sizes that range from those suitable for control of a single building with a few thousand square feet of floor area, to systems capable of controlling any number of buildings of unlimited size.

FEASIBILITY REQUIREMENTS:



Principal Feasibility Factors:

- Present annual energy consumption
- Cost of EMCS (acquisition, installation and startup)
- Number of candidate individual energy management schemes with favorable Savings to Investment Ratio (SIR's)
- Occupancy pattern instability
- Number of areas or zones which can benefit from individual control
- The energy savings that can be realized by HVAC schemes not presently implemented

A qualitative assessment of EMCS feasibility can be developed by considering the factors above. A rigorous quantitative assessment requires developing the savings projected from application of the individual energy conservation schemes to be incorporated with the EMCS program, as well as quantifying the additional benefits that result from their integration into a flexible central control system. Such analysis is beyond the scope of this manual. However, a rough indication, that may help in deciding if further analysis is warranted, can be obtained using the method shown under "Procedure."

BENEFITS/DETRIMENTS: EMCSs add complexity and require both hardware and software maintenance. The technologies involved may require some retraining, replacement or augmentation of existing maintenance personnel. However these factors may be more than offset by the numerous benefits of the system (which translate into maintenance, energy and cost saving). Summarily, the benefits are:

- Control Scheme Flexibility - the ability to implement multiple control strategies of virtually unlimited complexity, and relative ease of change.

- Scheduling Flexibility - the ease with which adjustments to either short-term or long-term occupancy or building usage schedules may be made.

- Maintenance Benefits - the monitoring, data collection and analysis, and report generation. This can provide fault isolation and analysis, indicate need for corrective maintenance, and assist with preventative maintenance scheduling.

- Energy Saving - a properly designed EMCS can achieve greater energy savings than are obtainable by any alternative approach.

SURVEY DATA NEEDS:

- Present annual energy consumption (MBtu/yr)
- Number of candidate individual energy management schemes (ECOs) with favorable SIRs (ECOs HVAC 15-23)
- Number of zones or areas that would benefit from individual control
- Occupancy and usage patterns, including projected stability of these factors
- Building specifics sufficient to calculate building thermal transmission factor (see Supporting Data: paragraph SD 2-2

PROCEDURE:

The following procedure can only provide some indication of the cost effectiveness of an integrated EMCS installation. The procedure presumes that each area that has, or may have, a different usage (of HVAC energy consumption significance) than adjacent areas, constitutes a zone that would be separately controlled by the EMCS. It is also presumed that all strategies with a significant savings potential would be incorporated.

1. Complete the following evaluation chart and sum the weighted score column (D).

2. The EMCS savings factor (SF) estimate is then computed as follows:

   SF = Total Weighted Score x 0.031

HVAC 14. EVALUATION CHART

A EMCS Potential Saving Factor	B Score*	C Weighting Factor	D Weighted Score (B x C)	E Max Weighted Score
1. Changes in occupancy and usage pattern	(0-4)	1		4
2. Average percent of space unoccupied time, and allowable temperature	(0-4)	BTT** Value		8
3. Air economizer savings potential	ESF** Value	0.2		5
4. Total number of potentially applicable control strategies to be incorporated in EMCS program (Number = N)***	N	1		3
			Totals	20

*For scoring column B, use following 0-4 subjective values:

0 - negligible or not applicable change
1 - small change
2 - medium change
3 - large change
4 - extreme change

**See Supporting Data section for explanation of the variables "ESF" and "BTT."

***Check feasibility requirements of HVAC 15-23 for possible control strategies to be incorporated.

3. Annual energy cost savings (ΔE), is calculated by multiplying the existing average annual energy cost for the areas considered by the savings factor (SF) determined in step 2. (Note: This calculation does not take into account any change in operation and maintenance costs.)

GENERAL INFORMATION:

Sizes Available: For buildings of a few thousand square feet and larger. No upper limit on building size, number of control points, or number of buildings.
Startup Cost: $10,000 to $100,000 (see "EMCS Cost Estimating Data" (NCEL Report No. CR83.008))
Replacement Cost: Same as startup cost
Equipment Life: 15 to 25 years
Skill Level of Personnel Required: Engineers, computer programmers, electrical and mechanical technicians
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available On Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating Plant Efficiency (HEFF): 75%
Startup Cost: $25,000
Existing Average HVAC Energy Cost: $18,000/yr
(176,000 kwh @ $0.08/kwh + 766 MBtu @ $5.12/MBtu)
ESF Value: 15
BTT Value: 1
Number of EMCS Control Strategies to be Employed: 9
Changes in occupancy and usage: medium (score 2)
Average % of space unoccupied time and allowable temperature reset: medium (score 2)
Change in O&M: None
Fuel Saved: Electricity and No. 2 oil
Energy Cost: $0.08/kwh
$5.12/MBtu
Escalation Rate: 7%, 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Using the evaluation chart (with the above assumed values), the total weighted score is:

(2 x 1) + (2 x 1) + (15 x 0.2) + 9 = 10

EMCS Savings Factor (SF) = 10 x 0.031 = 0.31

ΔE = SF x (Existing Average Annual Energy Cost)
= 0.31 x $18,000 = $5,580

FUEL SAVINGS (MBtu/yr) =

0.31 x 766 MBtu/yr = 238 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

0.31 x 176,000 kwh/yr = 54,560 kwh/yr

NES (MBtu/yr) =

766 MBtu/yr + (176,000 kwh/yr x 11,600 Btu/kwh MBtu/10^6Btu)

= 2,800 MBtu/yr

FUEL COST SAVINGS ($/yr) =

238 MBtu/yr x $5.12/MBtu = $1,220/yr

ELECTRICITY COST SAVINGS ($/yr) =

54,560 kwh/yr x $0.08/kwh = $4,365/yr

$$SIR = \frac{\$1{,}220\ (20.05) + \$4{,}365\ (18.049)}{\$25{,}000\ (1.251)}$$

= 3.3

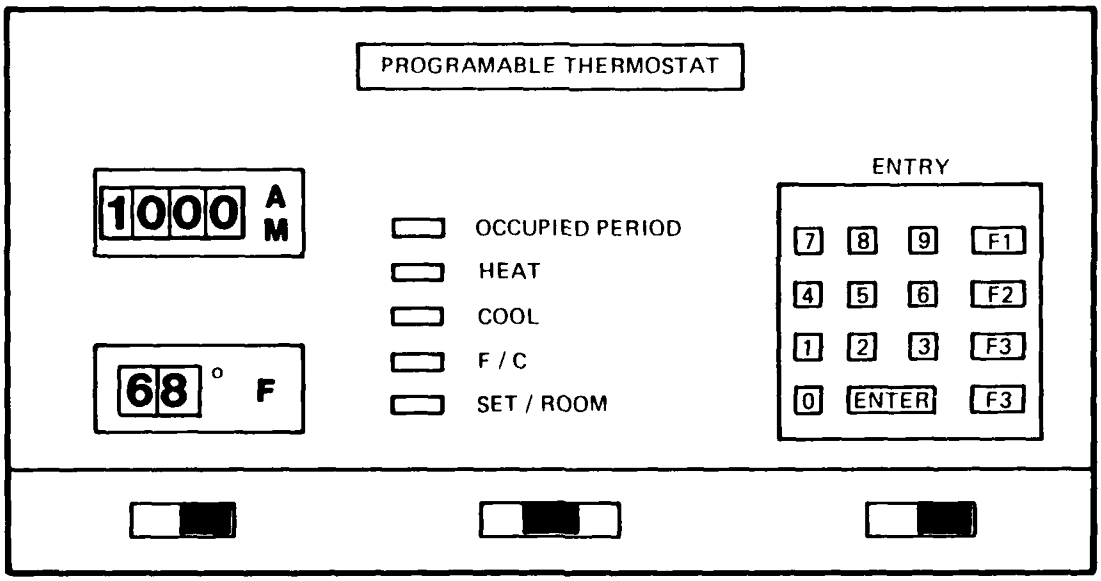


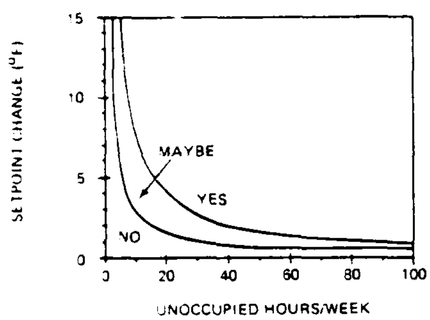
Figure HVAC-15. Day/Night Temperature Setback

HVAC 15. DAY/NIGHT TEMPERATURE SETBACK

DESCRIPTION: The energy required to maintain space conditions during the unoccupied hours can be reduced by changing the temperature set point. This strategy applies only to facilities that are not occupied 24 hours per day. Typically the interior design temperature would be reduced to 50 to 55°F at night during the unoccupied hours during the heating season, and set up to 85°F or more during the unoccupied hours during the cooling season.

Space temperature reset can be implemented in a variety of ways. The simplest method is the replacement of thermostats with ones having setback/setup features. More elaborate schemes permit controlling setback/setup differences and time changes from a central control station. The latter, while more expensive initially, is likely to prove much more satisfactory in service since tampering with settings is less likely to occur, and setting changes (time, heat/cool selection, temperature setpoint changes) does not involve visiting numerous individual thermostats.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Day and night temperature setpoint change is one of the most cost-effective HVAC energy conservation measures in situations where it can be applied. However, it is not applicable in situations where spaces are occupied continuously, or where space temperature must be maintained at specific levels for equipment or processes. A means must be provided to prevent unauthorized personnel from adjusting the time and temperature settings, if the potential savings are to be realized in practice.

SURVEY DATA NEEDS:

- Thermostat setup (SU) (°F)
- Building thermal transmission (BTT) (see Supporting Data SD 2-2)
- Area of zone (AZ) (ft^2)
- Heating and cooling system efficiencies (HEFF and EER)
- Hours per week during which temperatures must be maintained (H)
- Number of zones to be controlled
- Thermostat setback (SB) (°F)
- Weeks of winter (WKW) (see Supporting Data paragraph SD 1-11)
- Weeks of summer (WKS) (see Supporting Data paragraph SD 1-11)

PROCEDURE:

(Refer to Supporting Data for explanation of variables)

1. Fuel Savings (MBtu/yr), ESH =

$$\frac{BTT \times AZ \times SB \times (168 - H) \times WKW}{HEFF \times 1{,}000{,}000}$$

2. Electrical Savings (kwh/yr), ESC =

$$\frac{BTT \times AZ \times SU \times (168 - H) \times WKS}{1{,}000 \times EER}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: \$100 to \$300 per setback thermostat
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating Plant Efficiency (HEFF): 75%
Startup Cost: \$2,000 (10 thermostats at \$200 each)
BTT = 0.7 Btu/hr °F-ft^2
Building Area (AZ): 20,000 ft^2
Summer Setup (SU): 10°F
Winter Setback (SB): 10°F
Cooling Energy Efficiency Ratio (EER): 6.8 Btu/wh
Operating Time Per Week (H): 50 hours
Summer Length (WKS): 26 weeks
Winter Length (WKW): 26 weeks
Change in O&M: \$20 (increase)
Fuel Saved: Electricity for cooling; natural gas
Energy Cost: \$0.08/kwh
\$6.00 MBtu
Escalation Rate: 7%, 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

FUEL SAVINGS (MBtu/yr) = ESH =

0.7 Btu/hr-°F-ft^2 x 20,000 ft^2 x 10°F x (168 - 50 hr/wk) x 26 wk/yr x (1/(0.75 x 1,000,000 Btu/MBtu)) = 572.7 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) = ESC =

(0.7 Btu/hr-°F-ft^2 x 20,000 ft^2 x 10°F x

(168 - 50 hr/wk) x 26 wk/yr) x

(1/(6.8 Btu/wh x 1,000 wh/kwh))

= 63,165 kwh/yr

NES (MBtu/yr) =

572.7 x MBtu/yr + (63,165 kwh/yr x 11,600 Btu/kwh

x MBtu/10^{6}Btu)

= 1,305 MBtu/yr

FUEL COST SAVINGS ($/yr) =

572.7 MBtu/yr x $6.00/MBtu

= $3,436/yr

ELECTRICITY COST SAVINGS ($/yr) =

63,165 kwh/yr x $0.08/kwh

= $5,053/yr

SIR =

$$\frac{\$3,436\ (20.050) + \$5,053\ (18.049) + (-20)\ (9.524)}{\$2,000\ (1.251)}$$

= 64

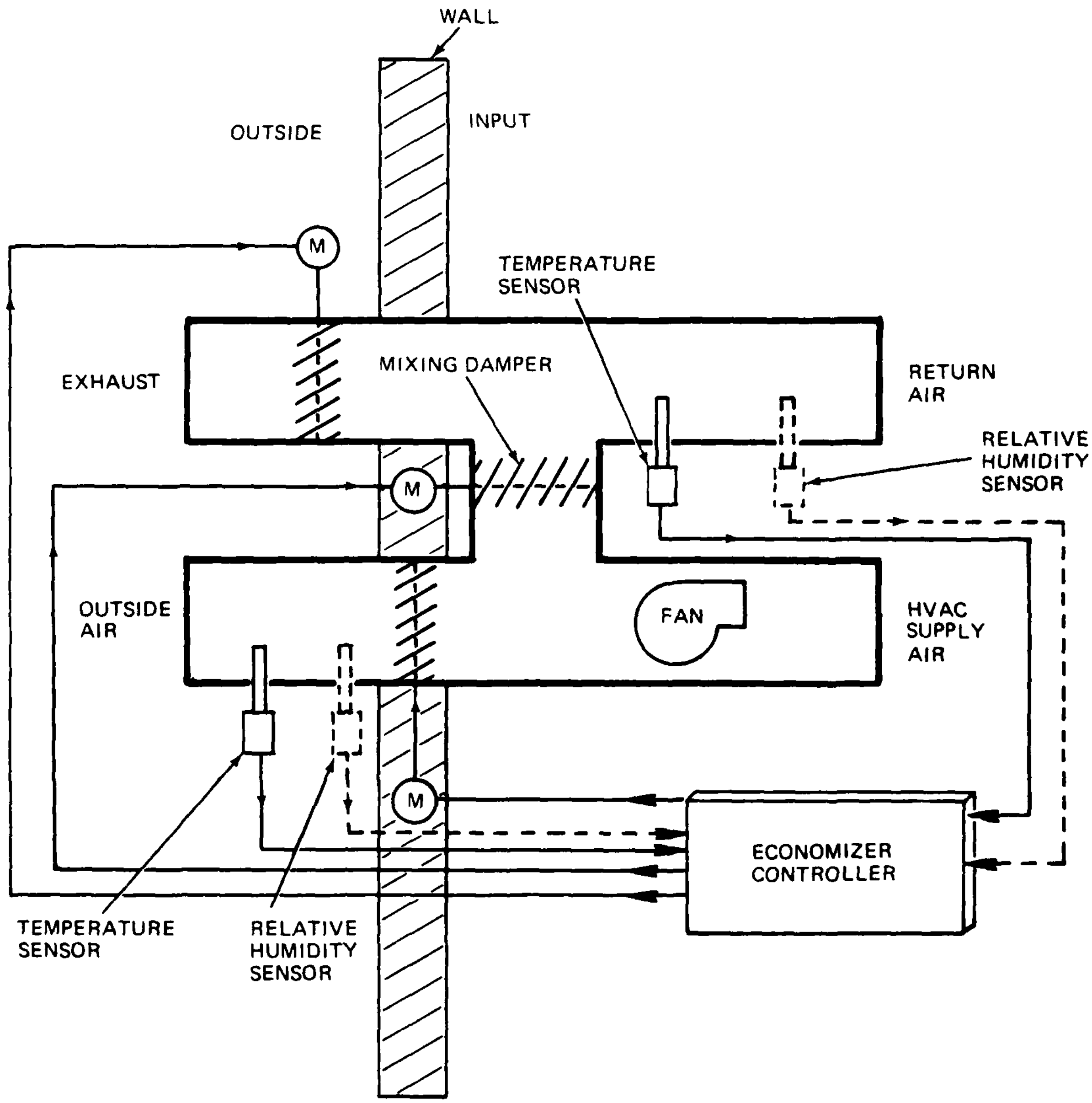
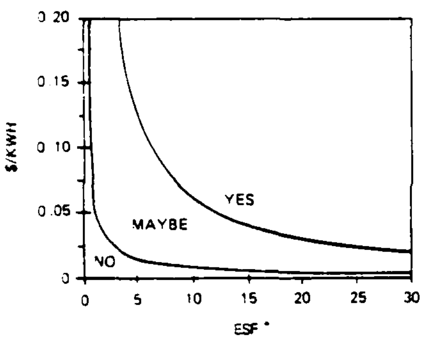


Figure HVAC-16. Air Economizers

DESCRIPTION: Economizer systems consist of outside air intakes and remotely controlled dampers that allow selection of the normal mix of outside and return air or 100% outside air as the HVAC system's input. (See illustration on facing page.) In essentially all geographic areas there are periods during the cooling season when it is more economical to process outside air. The intent of economizer systems is automatic selection of the proper source.

Two types of economizer damper control systems are on the market. The first type makes decisions based only on outside air dry bulb temperature. This measurement is then compared to either a predetermined setpoint, or to the dry bulb temperature of the return air. But the source of air that is more economical to process, depends not just on the temperature of one compared to the other, but also on the relative enthalpy on the individual air source. Enthalpy can be computed from either dry bulb and wet bulb temperatures, or from dry bulb temperature and relative humidity. Therefore, controllers that respond only to dry bulb temperatures can cause source selection that is more expensive to process. The second type of controller, which is designed to make source selection based on enthalpy, would in theory avoid the possible selection errors that can occur when only dry bulb temperatures are measured (also see "Benefits/Detriments" discussion).

FEASIBILITY REQUIREMENT:



* See Supporting Data Section Table SD2

Feasibility depends both upon the type of HVAC system installed, as well as the climatic conditions. The feasibility curve is based on constant volume hot deck/cold deck or terminal reheat system. For other types of systems, the savings would have to be derated by the cooling system loading factor (LS) (ratio of average total season cooling provided to the cooling that would have been provided if the system operated at full capacity during the full number of cooling hours available in the season). If no better value is available assume a derated ratio of one third.

Climatic conditions are accounted for by the ESF factor values in Weather Data Table SD2 contained in the Supporting Data section. These values were computed from Engineering Weather Data, NAVFAC (P-89), and provide the average over the cooling season of cooling avoided (in MBtu per 1,000 cfm for air cooled to 55° F, based on a 50 hour week - if outside air is used whenever it is more economical to process).

Economizers are available with either constant volume or variable volume air systems. Hot deck/cold deck or terminal reheat constant volume systems normally provide the most benefit. This is due to the fact that with these type systems, cooling is being provided constantly during the cooling season, presenting the opportunity to take advantage of "free cooling" a greater percentage of the time. With variable volume systems, cooling is provided only when heat generated internally exceeds building heat losses (such as during the warm parts of the day). However these periods tend to correspond to periods when outdoor air enthalpy (or temperature) is too high. As a rough rule of thumb, the savings for variable volume systems will be on the order of a third of those for constant volume systems of the same capacity.

Obviously the cooler and dryer the climate, the greater the potential for economizers to be cost effective. There is simply little potential for savings in normally hot humid climates.

BENEFITS/DETRIMENTS: While the potential for savings exists in some cases, practical results often fall short of expectations. Improper choice of the air source by the controller can result in greater energy expenditures than before economizers were installed. Such occurrences are hard to guard against since they are not accompanied by any overt indications.

Economizer systems that respond only to dry bulb temperatures must have the switchover temperatures set to minimize the probability of introducing outside air of a higher enthalpy than that of the return air, even though the outside air temperature might be lower. This (i.e., the lowered switchover setpoint) will necessarily result in the loss of all potential savings associated with the region of outdoor temperatures lower than the return air temperature but higher than the switchover setpoint temperature. This region typically would cover a significant portion of the total potential savings available from processing outside versus return air.

The use of enhalpy controllers would seem the ideal solution to the problems associated with control based only on dry bulb temperature. Enthalpy control, however requires measurement of relative humidity (or alternatively wet bulb temperature). Unfortunately, tests conducted by the Army's Civil Engineering Research Laboratory at Champaign, Illinois on a sampling of commercially available devices has shown that they are problem prone. Typically they do not retain sufficient accuracy to consistently permit enthalpy determination to make the proper air source choice. A partial solution to this problem is frequent checking and replacement of sensors. If proper maintenance operation cannot be assured, there is a very real risk that none of the expected saving will be realized, or worse, that the system will be even more expensive to operate than before economizer installation. This possibility is all the greater since there is no overt indication of the controller having chosen to cool the air with higher enthalpy.

An additional problem with wrong air source selection is that of increased interior relative humidity. If outside air with a higher enthalpy is exchanged for inside air, relative humidity will increase (assuming a constant interior dry bulb temperature). Experience with economizer operation in humid geographic areas has shown this to be a serious problem which has resulted in significantly increased maintenance costs due to excess humidity precipitation problems (i.e., rust, etc).

In view of above potential problems, serious consideration should be given to rejecting use of economizers, even when the potential of significant savings is otherwise indicated, unless the installation is in conjunction with an adequate central Energy Management and Control System (EMCS). A properly designed EMCS can essentially eliminate the above problems by monitoring multiple humidity sensors, and thereby indicate when calibration or other maintenance actions are necessary, and prevent the introduction of outside air wherever accurate enthalpy determination is in question.

SURVEY DATA NEEDS:

- Type of HVAC system (constant or variable air volume)
- Air handling unit capacity (cfm)
- Required minimum outside air in % total air flow rate (FA)
- Hours per week (during the cooling season) that cooling is available (H)
- Cooling energy efficiency ratio (EER)
- Cooling system loading factor (LS). If system is a constant volume hot deck/cold deck or terminal reheat system, LS = 1. For other types of systems use a value of LS determined as follows: LS = CFLH/(WKS x 7 x 8)

(See Supporting Data for explanation of variables)

PROCEDURE:

1. Determine value of ESF by consulting the Weather Data tables (in Supporting Data Table SD2)

2. Electrical Savings (kwh/yr)* =

   (cfm/1,000 cfm) x (1-(FA/100)) x ESF (MBtu/yr) x

   H/50 hr/wk x ESF (Btu/yr) LS x (H/(50 hr/wk)) x

   1/EER (Btu/wh) x kwh/1,000 wh**

   Decrease this value by 7% if dry bulb temperature rather than enthalpy is to be used for control

   * assumes air being cooled to 55°F

   ** Use units for variables given with variable definitions in the Supporting Data section of this manual

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $3,000-$4,500
Replacement Cost: $3,000
Equipment Life: 15-25 years
Skill Level of Personnel Required: Sheetmetal workers and electricians
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

Electrical Energy Savings (in kwh/yr) x

(11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C\ (PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating Plant Efficiency (HEFF): 75%
Startup Cost: $4,000

SAMPLE CALCULATION - Continued

Control Variable: dry bulb temperature (derate savings 7% compared with enthalpy control)
Fresh Air (minimum) (FA): 5%
Operating (Cooling Available) Hours Per Week (H): 50
Air Conditioning Plant Efficiency (EER): 6.8
HVAC Type: constant volume terminal reheat
Project Equipment Useful Life: 15 years
Air Handling Capacity (CFM): 10,000 CFM
ESF value (from Weather Data Table in Supporting Data section: 15 Btu/yr
Change in O&M: $200 (increase)
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

From Weather Data Table in Supporting Data, ESF = 15

ELECTRICAL SAVINGS (kwh/yr) =

(10,000 cfm/1,000 cfm) x (1-(5/100)) x

15 MBtu/yr x (50 hr/wk/50 hr/wk) x

1 x (1/6.8 Btu/wh) x (kwh/1,000 wh)

= 2.10×10^4 kwh/yr

Derating by 7% (due dry heat temperature control)

= 1.95×10^4 kwh/yr

NES (MBtu/yr) =

0 + (1.95×10^4 kwh/yr x 11,600 Btu/kwh)

= 226 MBtu

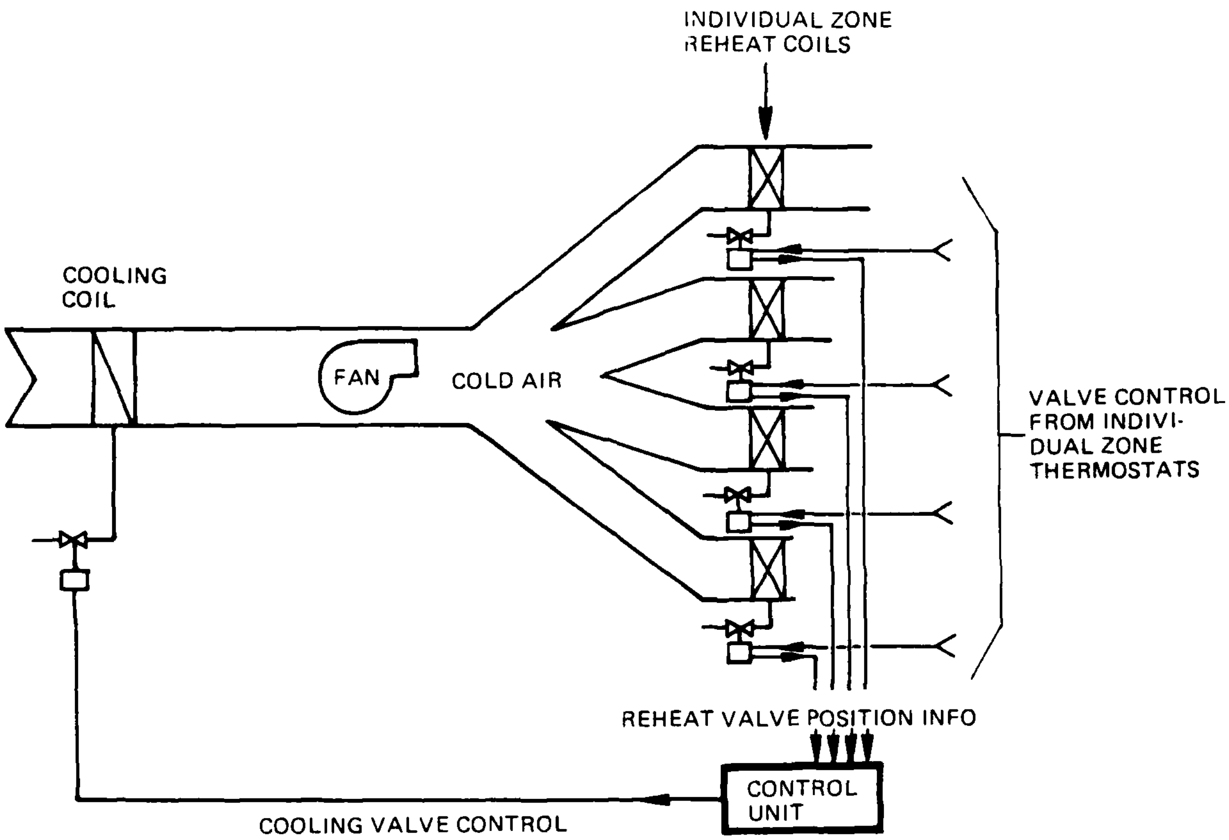
ELECTRICITY COST SAVINGS ($/yr) =

1.95×10^4 kwh/yr x $0.08/kwh

= $1,600/yr

$$SIR = \frac{\$1,560\ (18.049) + (-\$200)(9.524)}{\$4,000\ (1.251)}$$

= 5.2



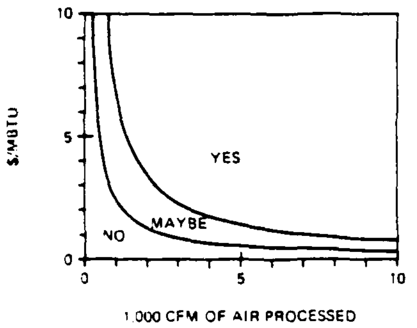
NOTE: CONTROL UNIT CONTINUOUSLY ADJUSTS INPUT TO COOLING COIL, AND THUS THE EXISTING COLD AIR TEMPERATURE, SO THAT (AT LEAST) ONE ZONE NEEDS NO REHEAT (REHEAT VALVE CLOSED) TO MAINTAIN ZONE SETPOINT EXHAUST TEMPERATURE

Figure HVAC-17. Minimize Use of Reheat

DESCRIPTION: Mechanical systems such as dual duct (i.e., parallel) systems and some multizone systems use a parallel arrangement of heating and cooling coils commonly referred to as hot and cold decks for the purpose of providing heating and cooling mediums simultaneously. Generally speaking, both heated and cooled air streams are mixed to satisfy the individual space thermal requirements. In the absence of optimization controls, these systems can waste energy because the final space control merely mixes the two air streams to produce the desired result. While the space conditions may be acceptable, the greater the difference between the temperatures of the two streams, the more inefficiently the system will operate. This strategy can select the individual areas with the greatest heating and cooling requirements, establish the minimum necessary hot deck and cold deck temperatures based on these extremes, and minimize the inefficiency of the system. The goal is to reduce the temperature difference between the two air streams to the minimum value which will still meet the zone conditions.

A variation of the hot and cold deck multizone system is the air handler equipped with a cold deck and individual heating coils located in the distribution branches downstream (i.e., series system). The system operates with a constant cold deck temperature which is, in turn, mixed with cold deck bypass air in an effort to satisfy individual zone requirements. Air supplied at temperatures below the individual space requirements is elevated in temperature by the reheat coil in response to signals from an individual space thermostat. Selection of the space with the greatest cooling requirements and resetting the cold deck discharge temperature in response to these requirements minimizes the energy used for reheat. Again the strategy is to minimize the temperature differences.

FEASIBILITY REQUIREMENT:



This strategy is applicable only to systems in which HVAC air is chilled, then subsequently reheated (either by mixing airstreams, or by passing the chilled air through a downstream heater). When the HVAC system is one of these types, considerable savings are often possible.

If the setpoints (i.e., cold deck and hot deck for parallel type systems) are simply manually reset, there is negligible cost (only the labor for resetting temperatures). This is clearly cost effective anytime the existing settings call for reheat even under the most demanding cooling conditions. Systems that dynamically reset temperature(s) require additional equipment, though greater savings are thereby possible. These may or may not be cost effective, depending upon startup costs and the savings that would result therefrom.

BENEFITS/DETRIMENTS: The benefit is a reduction, often significant, in HVAC energy consumption. If the deck temperature resetting is not excessive, there are no detriments. If the reset is excessive the design temperature in some spaces could not be maintained during peak HVAC load conditions.

SURVEY DATA NEEDS:

- Type of system: Hot deck/cold deck, or terminal reheat
- Capacity of air handling unit (CFM)
- Length of cooling season (WKS)
- Cooling Energy Efficiency Ratio (EER)
- Efficiency of heating system (HEFF)
- Hours of operation per week (H)
- Amount of summer and winter reset possible (RHR, SCDR, and SHDR) (see Glossary)

PROCEDURE: (see Supporting Data for explanation of variables).

1. Calculate reset factors (RF) as follows:

   a. For electrical savings:

      1) For parallel (i.e., hot deck/cold deck) system:

         RF_C = SCDR x WKS

      2) For series (i.e., terminal reheat) system:
         RF_C = RHR x WKS

   b. For fuel savings:

      1) For parallel system:
         RF_H = (WKS x SHDR + WKW x WHDR)

      2) For serial system:
         RF_H = RHR x 52

2. Fuel Savings (MBtu/yr) = ESH =

$$= \frac{H \times CFM \times HD \times (1.08 \text{ min MBtu/yr})}{HEFF \times (10^6 \text{ hr-ft}^3\text{-}^oF)} \times RF_H$$

3. Electrical Savings (kwh/yr) = ESC =

$$= \frac{H \times CFM \times CD \times (2.7 \text{ min-ton})}{1{,}000 \text{ ft}^3\text{-}^oF \times EER} \times RF_C$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: From negligible (for manual resetting of a single hot deck/cold deck unit, to several thousand dollars for dynamic and/or remote resetting systems)
Replacement Cost: Same as startup
Equipment Life: 15 to 25 years
Skill Level of Personnel Required: Normal maintenance personnel, electrician, and/or design personnel depending upon system
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Heating Plant Efficiency (HEFF): 75%
- Startup Cost: $1,000
- System Type: Terminal reheat (therefore CD = HD = 1 i.e. series.)
- Cooling Season Length (WKS): 26 weeks
- Air Flow Rate: 10,000 cfm
- Cooling Energy Efficiency Ratio (EER): 6.8
- Hours of Operation Per Week (H): 50 hours
- Amount of Reset (RHR): 3° F
- Change in O&M: None
- Fuel Saved: Gas & electricity
- Energy Cost: $0.08/kwh
  $6.00/MBtu
- Escalation Rate: 7%, 8%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$RF_C = 3^{\circ} \times 26$ weeks = 78

$RF_H = 3^{\circ} \times 52$ weeks = 156

FUEL SAVINGS (MBtu/yr) =

$$\frac{50 \times 10{,}000 \times 1 \times 1.08}{0.75 \times 10^6} \times 156 = 112 \text{ MBtu/yr}$$

ELECTRICAL SAVINGS (kwh/yr) =

$$\frac{50 \times 10{,}000 \times 1 \times 2.7}{1{,}000 \times 6.8} \times 78 = 15{,}500 \text{ kwh/yr}$$

NES (MBtu/yr) =

112 MBtu/yr + (15,500 kwh/yr x

11,600 Btu/kwh MBtu/10^6 Btu) = 292 MBtu/yr

FUEL COST SAVINGS ($/yr) =

112 MBtu x $6.00/MBtu = $672/yr

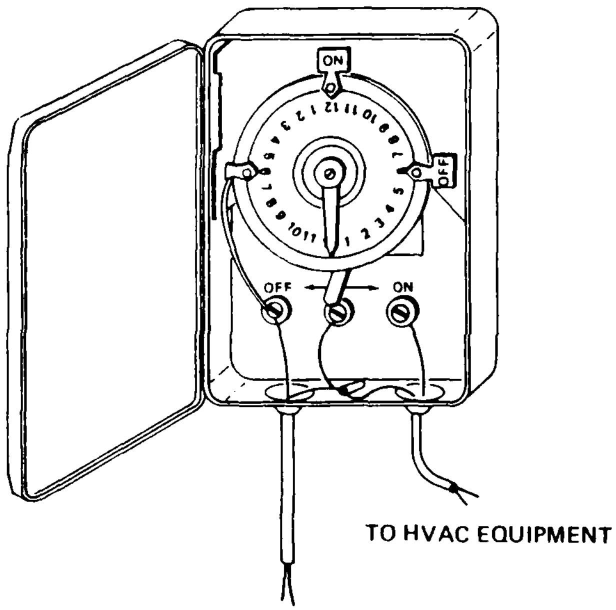
ELECTRIC COST SAVINGS ($/yr) =

15,500 kwh x $0.08/kwh = $1,240/yr

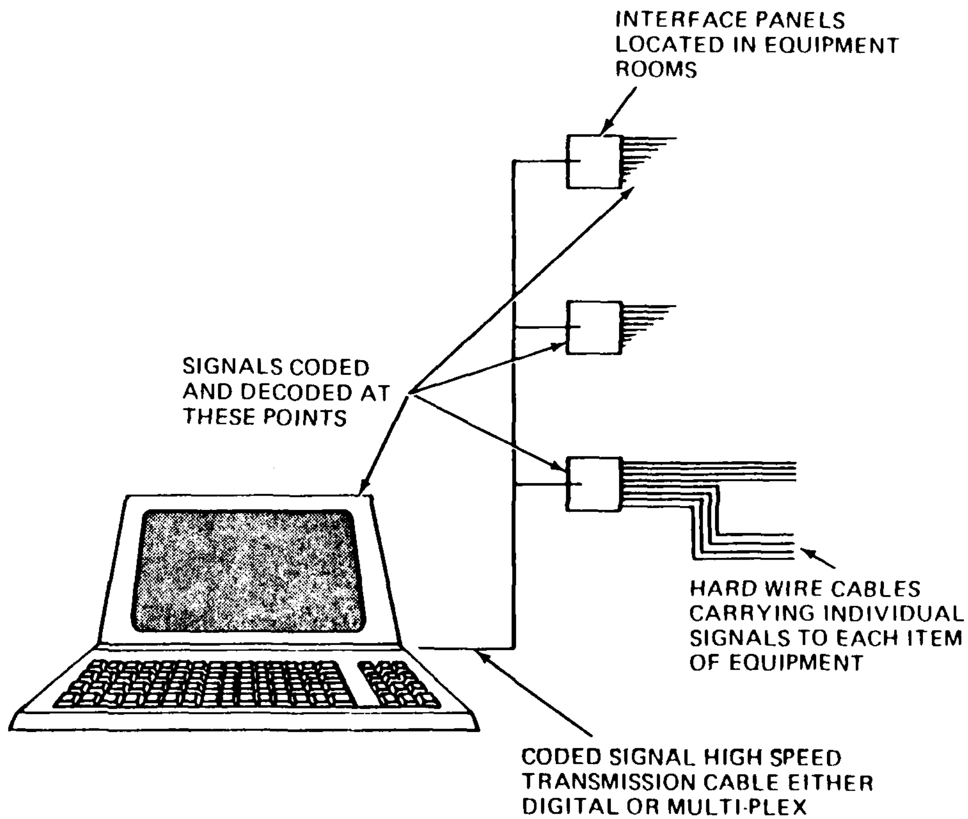
SIR =

$$\frac{(\$672)(20.35) + (\$1{,}240)(18.049) + 0}{1{,}000\ (1.251)}$$

= 29



a) SIMPLE TIMECLOCK CONTROL



b) INCORPORATED AS PART OF AN EMCS

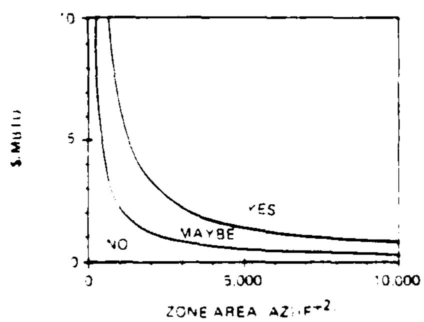
Figure HVAC-18. Scheduled Start/Stop Operation

DESCRIPTION: Time-scheduled operation consists of the starting and stopping of equipment, or the resetting of operating points, based on the time and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. It is the simplest of all control systems to install, operate, and maintain. It can be applied to an HVAC system as a whole, or to individual portions or functions thereof. This ECO, however, addresses only the situation wherein a timeswitch (or other time based control equipment) is used to prevent operation of the HVAC system during (most of) the unoccupied periods of a building or space under consideration. This scheme is appropriate where occupant health and comfort are the only reasons for maintenance of atmospheric conditions.

Closely related to this control strategy are optimum (vice scheduled) start/stop (HVAC 19), and scheduled operating point set/reset (vice start/stop) control (HVAC 15). A situation that looks promising for any one of these strategies needs to be examined in light of the others as well. Sometimes a combination of strategies makes sense. Indications that a combination strategy is appropriate, however, is in turn reason to consider some form of total Energy Management Control System (EMCS). See HVAC 14 for an overview of EMCSs.

Also closely related to this control strategy is time-based control over the introduction of outside air for ventilation (HVAC 22). While heating (or cooling) must begin sometime prior to the start of the occupied period in order for temperature to reach setpoint temperature following a shutdown period, no ventilation air is required during this period. Moreover, the thermal load imposed by its introduction can be significant. Avoiding heating (and to a much lesser degree cooling) this air during the warmup (or cooldown) period could thus save considerable energy. The start/stop times for outside air are different than system start/stop times, however, and thus may require a separate timeswitch. The savings that result from this, computed in accordance with the HVAC 22 procedures, must be added to the savings resulting from start stop operation for total energy saved.

FEASIBILITY REQUIREMENT: (For HVAC shutdown during unoccupied hours.)



BENEFITS/DETRIMENTS: Scheduled stop/start operation is among the simplest and least expensive of the Energy Management functions to implement, and can result in significant energy savings by preventing HVAC energy consumption when all or some of the system's functions are not needed. Properly applied, there are no detriments. Note, however, when this scheme is used to prevent the introduction of outside (i.e., ventilation) air during a building's unoccupied warm up period, savings are possible only during the heating season. Excluding cool, morning outside air during the cooling season may actually increase energy costs. Therefore, when implementing this function, a means of disabling the function must be provided.

SURVEY DATA NEEDS:

- Determine for each HVAC unit:
  - o The system capacity in CFM
  - o Required minimum outside air % total air flow rate (FA)
  - o The number of hours of normal operation/week that the equipment can be turned off compared to the present operation
- Zone area (ft^2)
- Determine the number of degrees setback or setup (SB, SU) acceptable
- Cooling Energy Efficiency Ratio (EER)
- Heating Plant Efficiency (HEFF)

PROCEDURE: (See Supporting Data section for explanation of variables.)

The following savings calculations for HVAC equipment assume a low temperature override to system shutdown. If no low temperature limit is desired then use the average winter temperature (AWT) in place of the low temperature limit (LTL) and let percent runtime (PRT) equal zero.

1. Cooling energy savings (ESC) (in kwh/yr) =

$$\frac{BTT \times AZ \times (AST - SSP) \times (168 - H) \times WKS}{1{,}000 \times EER}$$

2. Heating energy savings (ESH) (in MBtu/yr) =

$$\frac{BTT \times AZ \times (WSP - LTL) \times (168 - H) \times WKW}{1{,}000 \times HEFF}$$

3. Ventilation cooling energy savings (ESC_V) (in kwh/yr) =

$$\frac{CFM \times FA \times 4.5 \times (OAH - RAH) \times (168 - H) \times WKS}{1{,}000 \times EER}$$

4. Ventilation heating energy savings (ESH_V) (in MBtu/yr) =

$$\frac{CFM \times FA \times 1.08 \times (WSP - AWT) \times (168 - H) \times WKW}{(10^6 \times HEFF)}$$

5. For any auxiliaries not accounted for by EER (cooling energy efficiency ratio) and HEFF (heating plant efficiency) values:

   Electrical Savings (ESA_{SS}) (in kwh/yr) =

$$HP \times L \times (0.746\ kw/hp) \times (168 - H) \times \left[WKS + (WKW \times (1 - PRT))\right]$$

6. Total Fuel Savings (MBtu/yr) =

$$ESH + ESH_V$$

7. Total Electrical Savings (kwh/yr) =

$$ESC + ESC_V + ESA_{SS}$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $100 and up, depending on features and number of systems or devices to be controlled.
Replacement Cost: Same as startup cost
Equipment Life: 15 to 25 years
Skill Level of Personnel Required: Electrician, design personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{(E_{fuel})(DERF) + (E_{elec})(DERF) + (O\&M)(PYDF)}{(I)(PIF)}$$

SAMPLE CALCULATION (for entire HVAC shutdown):

Assumptions:
- Startup Cost: $500
- Low Temperature Limit: None
- Average Winter Temperature (AWT): 45 °F
- Area of Zone Being Served (AZ): 20,000 ft^2
- Building Thermal Transmission (BTT): 1.0 Btu/hr-°F-ft^2
- Air Handling Capacity: 10,000 ft^3/min
- Cooling Energy Efficiency Ratio (EER): 6.8
- Hours of Operation Per Week (H): 50
- Heating Plant Efficiency (HEFF): 75%
- Average Outside Air Enthalpy (OAH): 25 Btu/lb
- Required Minimum Outside Air % Total Air Flow (FA): 50%
- Percent Run Time During Heating Season Shutdown Period (required to maintain a low limit temperature) (PRT): 0%
- Return Air Enthalpy During Normal Operating Hours (RAH): 30 Btu/lb
- Length of Winter Heating Season in Weeks (WKW): 26 wk/yr
- Summer Thermostat Setpoint (SSP): 75°F
- Length of Summer Cooling Season in Weeks (WKS): 26 wk/yr
- Winter Thermostat Setpoint (WSP): 68°F
- Life Expectancy: 15 years
- Additional Auxiliaries Energy Saved: None (EAsg = 0)
- Change in O&M: $1,000/year (increase)
- Fuel Saved: Gas and electricity
- Energy Cost: $0.08/kwh, $6.00/MBtu
- Escalation Rates: 7%, 4%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Cooling energy savings (ESC) =

$$\frac{[illegible]}{[illegible] \times 6.8}$$

= [illegible] kwh/yr

Heating Energy Savings (ESH) =

$$\frac{[illegible]}{10^6 \times [illegible]} =$$

= [illegible] MBtu/yr

Ventilating cooling energy savings (ESC_V) =

$$\frac{10,000 \times 0.5 \times 4.5 \times (33 - 30) \times (168 - 50) \times 26}{1,000 \times 6.8}$$

= 30,454 kwh

Ventilation heating energy savings (ESH_V) =

$$\frac{10,000 \times 0.5 \times 1.08 \times (68 - 45) \times (168 - 50) \times 26}{10^6 \times 0.75}$$

= 508 MBtu

FUEL SAVINGS (MBtu/yr) =

1,064 MBtu/yr + 508 MBtu/yr

= 1,572 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

45,117 kwh/yr + 30,454 kwh/yr

= 75,570 kwh/yr

NES (MBtu/yr) =

x 1,572 MBtu/yr + (75,570 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu)

= 2,450 MBtu/yr

FUEL COST SAVINGS ($/yr) =

1,572 MBtu/yr x $6.00/MBtu

= $9,430/yr

ELECTRICITY COST SAVINGS ($/yr) =

75,570 kwh/yr x $0.08/kwh

= $6,045/yr

SIR =

$$\frac{\$9,430\ (20.050) + \$6,045\ (18.049) + (-\$1,000)\ (9.524)}{\$500\ (1.251)}$$

= 461

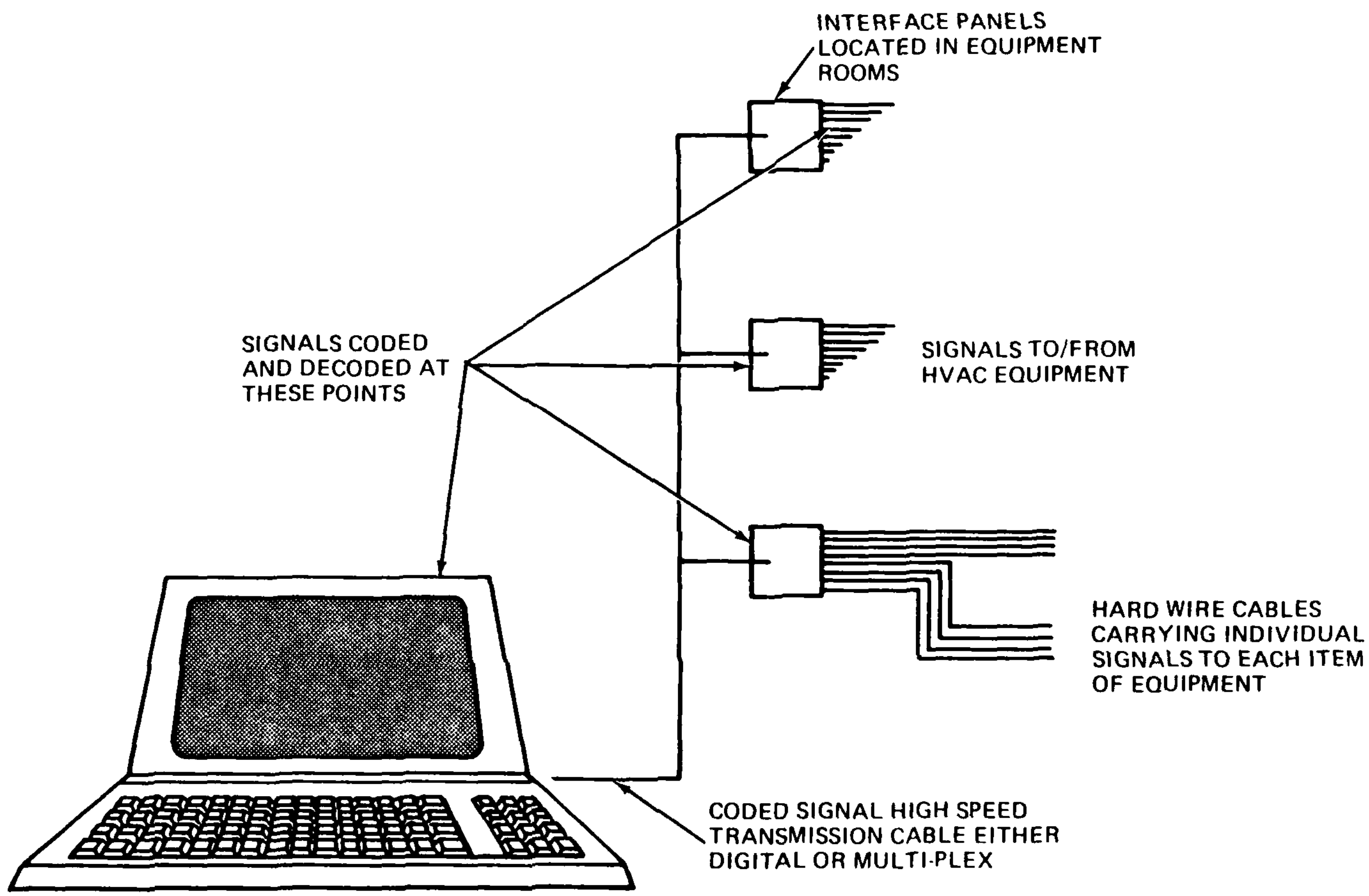


Figure HVAC-19. Optimum Start/Stop

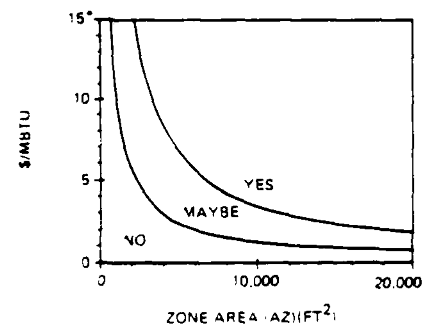
HVAC 19. OPTIMUM START/STOP

DESCRIPTION: Optimum start/stop is similar to scheduled start/stop. The difference is that rather than occurring at a scheduled time, morning startup is delayed until the remaining time prior to occupancy is just sufficient to permit reaching the setpoint temperature by the start of the occupancy period. Early (i.e., prior to the end of the occupancy period) shutdown of the HVAC system also may be possible, especially if ventilation is not critical and most building occupants leave at the scheduled time. For optimum start/stop, the controller automatically evaluates the thermal inertia of the structure, the capacity of the HVAC system to either increase or reduce the temperatures, scheduled occupancy times, and weather conditions in order to determine the minimum hours of operation to satisfy the thermal requirements of the building. From an energy conservation standpoint, this is an improvement over simple scheduled operation (HVAC 18) which must provide enough time to meet the demands of the worst case situation.

There are two components of energy savings that optimum start/stop control provides as compared to simple scheduled start/stop. The first is the reduction in runtime of system auxiliaries that normally run continuously. The second is the reduction in on-time of the cycling loads (such as unit heaters). This second component is generally small because the heat that must be added (or removed from a building) to get it to the setpoint temperature is the same regardless of when the warmup (or cooldown) commences. Thus this component of energy is that needed to maintain setpoint conditions for the periods equal in length to the difference between the optimum start (or stop) times and what would have to be the scheduled start (and stop) times. Since this component is both difficult to calculate and generally small, it is not included in the calculations for this ECO. Since this ECO only deals with the first component, it has applicability only to systems with a significant (normally continuously operating) auxiliary load.

As is the case of scheduled start/stop, this scheme should be used in conjunction with ventilation air control (HVAC 22).

FEASIBILITY REQUIREMENT:



* Curves shown can be used for system startup costs (c) other than the $2,500 used. For example, if C_{NEW} = 1,000 (i.e., 2/5 of $2,500) the unit cost scale maximum value becomes 2/5 x $15/Btu = $6 per Btu

This technique can provide significant savings - over and above those obtainable with simple scheduled start/stop operation and proper outside air dampers control - only where the HVAC system includes large noncycling auxiliaries (such as water pumps and/or constant velocity system blowers.) Thus the strategy generally has application only on larger, central HVAC systems.

BENEFITS/DETRIMENTS: The savings result from an increase in the setback period length compared to simple scheduled start/stop. This time interval varies from day to day but typically will average 1/2 hour a day.

(Later start of the HVAC system would also reduce the amount of outside air which must be conditioned if there were no separate control of outside air. However, outside air dampers should be controlled separately since that will provide significant savings. (Ventilation savings is dealt with separately in ECO HVAC 22.)

SURVEY DATA NEEDS:

- Determine for each HVAC unit:
  - The system capacity in CFM
  - Required minimum outside % total air flow rate (FA)
- Determine zone area of the building (AZ) (ft^2)
- Determine the number of degrees setback or setup (SB, SU)(°F) acceptable
- Total horsepower (HP) of continuously running auxiliary motors
- Equipment operational days per week (H)
- Present warmup time (hr)

PROCEDURE: (See Supporting Data section for explanation of variables.)

These procedures calculate only the savings over and above those realized by scheduled start/stop control. Therefore these savings, resulting from reduced auxiliary runtime, must be added to those calculated by HVAC-18 procedures for total optimized start/stop savings.

1. Calculate annual warmup auxiliary energy savings*, as follows:

   HP x L x (0.746 kw/hp) x ((WH x AND) - ERT) x (DAY/7 days/wk)

2. Calculate annual cooldown auxiliary energy savings*, as follows:

   HP x L x (0.746 kw/hp) x (CH - 0.75 hr/day) x (365 days/yr - AND) x (DAY/7 days/wk)

3. Total auxiliary energy savings ESA_{OS} in kwh/yr = warmup auxiliary energy savings + cooldown auxiliary energy savings

4. Fuel Savings (MBtu/yr) (see HVAC 18 procedure steps 2 and 4) = ESH + ESH_V

5. Electrical Savings (kwh/yr) (see HVAC 18 procedure steps 1, 3, and 5) =

   ESC + ESC_V + ESA_{SS} + ESA_{OS}

* This calculation assumes a 45-minute (0.75 hours) cooldown time is required per day during the days of the year not requiring warmup. This is a conservative estimate; in most parts of the country, a fifteen minute purge would probably be sufficient in mild weather.

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: Will vary greatly depending upon the type of controller used and whether control is combined with other strategies. $2,000 +
Replacement Cost: Same as startup cost
Equipment Life: 15 to 25 years
Skill Level of Personnel Required: Design personnel and electricians

Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Heating Plant Efficiency (HEFF): 75%
- Startup Cost: $2,500
- Total horsepower (HP) of continuously run auxiliaries*: 25 horsepower
- Estimate of electrical motor load factor (L) (see Supporting Data): 0.8
- Annual number of days total warmup required (AND) (see Supporting Data): 200 days/year
- Present cooldown time before occupancy (CH) (see Supporting Data): 2 hours/day
- Equipment operational days per week (DAY): 5 days/week
- Equipment run time total required for warmup (ERT) (see Supporting Data): 300 hours/yr
- Present warmup time before occupancy (WH): 2 hours/day
- Other assumptions same as for Scheduled Start/Stop (HVAC 18)
- Change in O&M: $1,000/yr (increase)
- Fuel Saved: Electricity and gas
- Energy Cost: $0.08/kwh, $6.00 MBtu
- Escalation Rate: 7%, 8%
- Annual Discount Rate (R): 10%

* Use nameplate horsepower (HP) times load factor (L) if actual horsepower of motor cannot be readily obtained (see Supporting Data section).

Calculations follow from the procedure section:

Annual warmup auxiliary savings =

25 x 0.8 x (0.746) x ((2 x 200)-300) x 5/7

= 1,067 kwh/yr

Annual cooldown auxiliary savings =

25 x 0.8 x (0.746) x ((2-.75) x (365-200)) x 5/7

= 2,198 kwh/yr

ESA_{OS} = 1,067 kwh/yr + 2,198 kwh/yr

= 3,265 kwh/yr

FUEL SAVINGS (MBtu/yr)* =

1,064 MBtu/yr + 508 MBtu/yr

= 1,572 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

45,117 kwh/yr + 30,454 kwh/yr + 0 + 3,265 kwh/yr

= 78,836 kwh/yr

NES (MBtu/yr) =

1,572 MBtu/yr + (78,836 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu)

= 2,486 MBtu/yr

FUEL COST SAVINGS ($/yr) =

1,572 MBtu/yr x $6.00/MBtu

= $9,432/yr

ELECTRICITY COST SAVINGS ($/yr) =

78,836 kwh/yr x $0.08/kwh

= $6,310/yr

SIR =

$$\frac{\$9,432\ (20.050) + \$6,310\ (18,049) + (-\$1,000)\ (9.524)}{\$2,500\ (1.251)}$$

= 94

* Values from HVAC 18

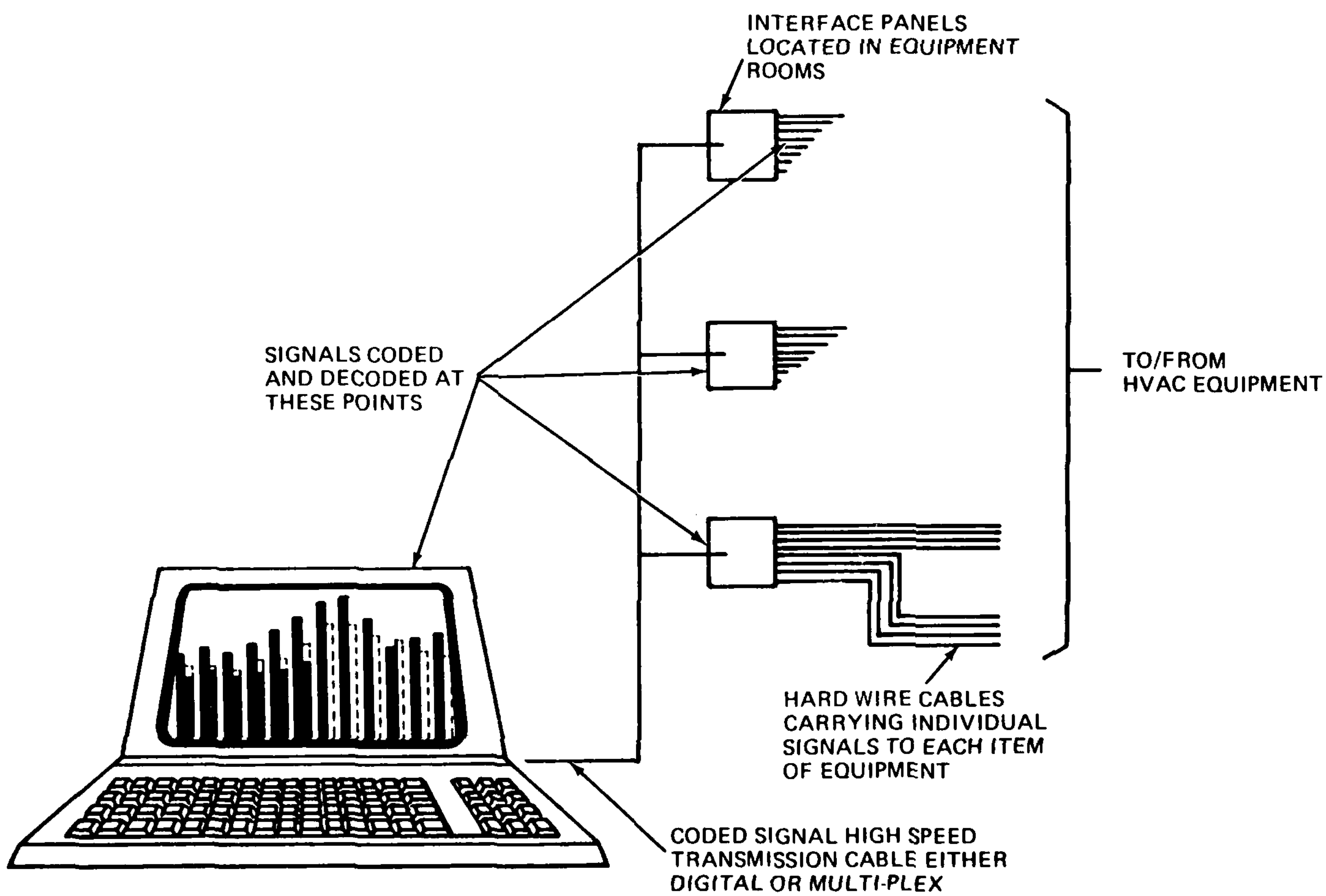
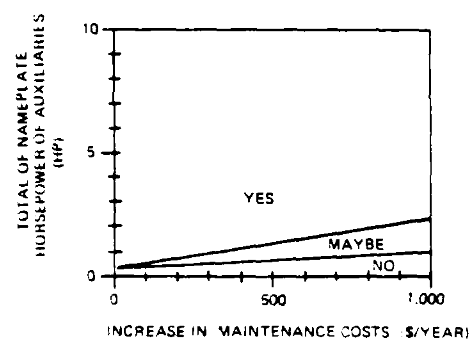


Figure HVAC-20. Duty Cycling

DESCRIPTION: Duty cycling periodically prevents operation of the HVAC system (or some portion thereof) for some fixed length of time. A typical cycle might call for disabling operation for ten minutes out of each hour.

There are three possible components to the savings that might thereby result. The first is that associated with reduced runtime of (normally) constantly running auxiliaries. The second is that associated with any reduction in the volume of ventilation (i.e., outside) air introduced (and thus that must be heated or cooled). The third possible component is that associated with the fact that the average space temperature will be slightly cooler in the winter and slightly warmer in the summer. For systems where duty cycling is feasible, this last item is generally negligible compared to the auxiliary savings. As for the second item, ventilation air processing, if outside air volume has already been reduced to the minimum acceptable level (see HVAC 22) no further outside air processing savings are possible. (Note: outside-air-to-return air ratio and duty-cycle-on/off-combined must still provide for minimum ventilation requirements. This may mean increasing the outside air percentage if duty cycling is implemented.) Thus, duty cycling savings becomes simply those savings resulting from reduction in the runtime of the (otherwise) continuously running auxiliaries. Obviously then this ECO is applicable only where such auxiliaries exist.

FEASIBILITY REQUIREMENT:



System must have continuously run auxiliaries that could periodically be shut down. Generally in auxiliaries with motors of more than 30 horsepower (if not designed for cycling), increased maintenance will more than offset the savings that might otherwise be realized.

BENEFITS/DETRIMENTS: In systems where noncycling auxiliaries exist, duty cycling can reduce HVAC energy consumption by reducing runtime. However, duty cycling does produce additional wear on belts and motor starting circuits. Further, it may affect air balance between zones if more than one air handler is in use. These problems may preclude use of this function in certain cases. Duty cycling is usually easy to implement, often involving a single controller (special time switch) and, where multiple motors are involved, relays for their control. The amount of off time that can be used usually must be determined experimentally. This, combined with the fact that it is impossible to accurately predict increased maintenance costs that will result, make any projection of SIR questionable.

SURVEY DATA NEEDS:

- Total of nameplate horsepower of all motors to be duty-cycled (HP)
- The hours per week that the HVAC system is normally operated (H)
- The number of minutes out of each hour that the system can be cycled off yet still maintain an acceptable degree of comfort*
- Heating Plant Efficiency (HEFF)

* This will depend upon a number of factors, and may not be the same for the cooling and the heating season. It may have to be determined experimentally, but usually off time can be 15% to 25% of normal operating time except during weather extremes.

PROCEDURE:

1. Electrical Savings Due to Duty-Cycling (of auxiliaries) (kwh/yr) = ESA =

$$HP \times L \times (10/60) \times (0.746\ kw/hp) \times H \times (52\ wk/yr)$$

where:

HP = Motor Nameplate Horsepower (total of all continuously running fans and pumps)

L = Load Factor (see Supporting Data)

10/60 = fraction of time system is shut down (assumes 10 minutes out of each hour)

H = Hours of Operation Per Week (use number of hours of occupancy assuming duty cycling is not desirable during warmup)

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $300 and up, depending upon number of individual motors to be duty cycled
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Design personnel, electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating Plant Efficiency (HEFF): 75%
Startup Cost: $500
Total Nameplate Horsepower: 45 (HP)
Normal HVAC system operation: 50 hours/week (H)
Duty cycle off time: 10 minute/hour
Projected equipment life: 15 years
Motor Load Factor (L): 0.8 (see Supporting Data)

Change in O&M: \$300/yr (increase)
Fuel Saved: Electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

ESA = 45 hp x 0.8 x 10/60 x (0.746 kW/hp) x 50 hr x

(52 wk/yr)

= 11,638 kwh/yr

NES (MBtu/yr) =

(11,638 kwh/yr x 11,600 Btu/kwh MBtu/10^6 Btu)

= 135 MBtu/yr

ELECTRICITY COST SAVINGS (\$/yr) =

(11,638 kwh/yr) (\$0.08/kwh)

= \$931/yr

SIR =

$$\frac{\$931\ (18.049) + (-\$300)\ (9.524)}{\$500\ (1.251)}$$

= 22

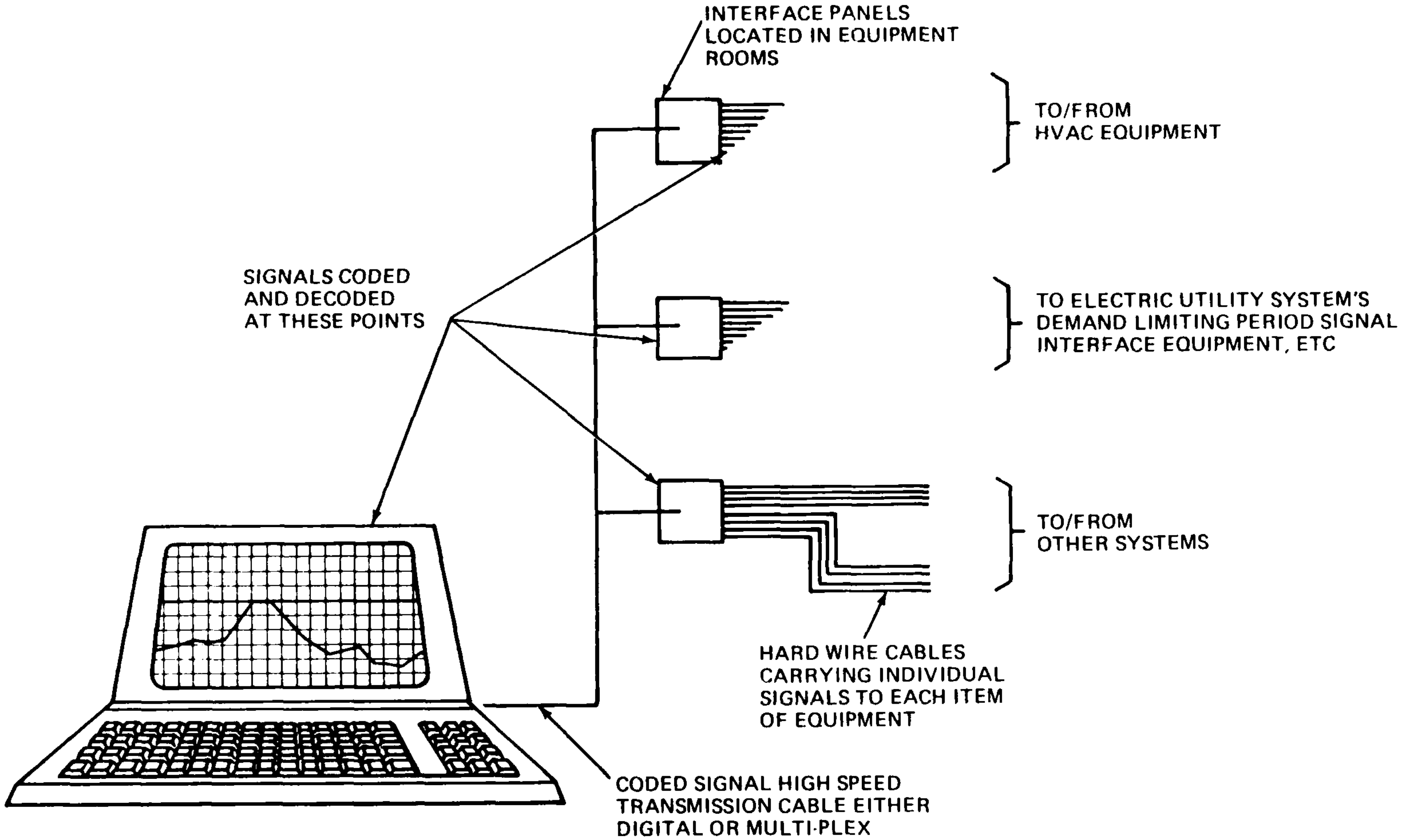


Figure HVAC 21. Demand Limiting

HVAC 21. DEMAND LIMITING

DESCRIPTION: saving energy is not the objective of demand limiting, although some savings are likely to result. The objective is a leveling of loads, to avoid peaks that would result in rate penalties. Much of the apparent energy saved during load-shedding periods will be consumed later, responding to pent up demand created during the load shed period. This strategy consists of reducing electrical loads to prevent a high electrical demand peak and thus decreasing electrical costs where demand oriented rate schedules apply. There are many complex schemes for accomplishing this which continuously monitor the electrical demand. Based on the monitored data, demand predictions are made by the control equipment. When these predictions exceed preset limits, certain scheduled electrical loads are shut off by the controller to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the strategy's requirements. Generally, the loads to be shed are HVAC items. The reasoning used in the duty cycling discussion (HVAC 20) holds here also:allow a slight temperature drift in the space by shutting off the HVAC equipment. Utility rate schedules, which include "time of day" pricing, offer additional savings opportunities. While this ECO is concerned only with HVAC systems, demand limiting or load shedding system planning should take into consideration all systems requiring large amounts of energy. Limiting the running of certain equipment, such as water well pumps, to off-peak hours can only have a large effect on the reserve available for other systems during periods when total demand must be limited. To realize the maximum benefit with a minimum of disruption in the normal course of business, a coordinated activity-wide plan (as opposed to a single system or building approach) is a must.

The energy saved from application of demand limiting to HVAC systems, as in the cases of scheduled and optimized start/stop, (HVAC 18 and 19), consists of two components: the first is that associated with reduced run time of system auxiliaries, and the second is that associated with the fact that average space temperatures will be somewhat higher (in the summer) or somewhat lower in the winter. This deviation from normal setpoint temperature(s) will (likely) be greater than that allowed with start/stop operation; thus, this component of saving will be proportionally larger. It is assumed that the introduction of outside air for ventilation has already been reduced to the lowest possible volume consistent with safety and health requirements (see HVAC 22) and thus presents no further potential for energy saving.

Feasibility Requirement: Because of the complexities associated with determining energy and energy cost savings that may accrue for demand limiting (i.e., load shedding), no single chart showing SIRs as a function of one or two variables would be meaningful. Feasibility is dependent upon the energy rate schedule structure, including formulas for cost during peak demand periods. These vary widely, and are often rather complex. Feasibility also depends on the length of time the HVAC system (or portions thereof) can be shut off and still maintain temperature and fresh air within minimum acceptable limits. The latter depends upon a number of variables, including the weather and building usage factors on any given day, as well as the full load capacity of the HVAC system. Health and comfort requirements, however, normally preclude turning off HVAC services to any given zone for more than approximately 15 minutes per hour. The actual tolerable off time usually has to be determined experimentally, by starting with some nominal value (e.g., 10 minutes) and adjusting from there. While penalties for high utility usage during peak demand periods may be steep, the length of these periods and the number of their occurrence during the year may be small enough that a load shedding system may be hard to justify on strictly a cost-effectiveness basis. Economic feasibility will increase if part of the control system is shared by other ECO schemes. In particular, demand limiting by selective load shedding may be a very cost-effective addition to an existing EMCS (see HVAC 14) whose program does not presently include this feature.

BENEFITS/DETRIMENTS:

- Making a determination as to the approximate saving in energy and energy costs that can be expected from selective load shedding can be very difficult. This is especially true when the peak usage period rate schedule is itself complicated, as is usually the case.

- The length and frequency of the off periods for those systems that cannot remain off for entire high usage penalty periods often must be determined experimentally.

- There will be increased maintenance costs, also very difficult to estimate, associated with those systems shut down as part of the load shed if those systems are not designed for cyclic operation. This increased maintenance cost can be quite significant for some equipments.

- Selective load shedding systems may be cost effective only where part of the system's costs are shared with other conservation schemes being implemented concurrently.

SURVEY DATA NEEDS:

- Utility company demand rate schedules
- Building(s) HVAC system(s) plans
- Energy input requirements for the (normally) constantly running auxiliaries for all systems and equipments to be taken off line as part of a load shed plan.

PROCEDURE: The procedure used will vary extensively, reflecting the local situation. The procedure that follows is an illustration only, and presumes a situation far simpler than any likely to be actually encountered. The procedure here (as in the scheduled and the optimized start/stop cases) calculates only the savings that result from reducing the run time of auxiliaries that would normally run continuously.

Assume by using a rotating group load shed scheme that each zone's auxiliaries can be shed 25% of time under peak load conditions.

1. Electrical Savings/Zone (kwh/yr) =

   HP x L x (0.746 kw/hp) x 0.25 x AND

where:

HP = Motor Nameplate Horsepower (total of all motors in system)

L = Load Factor (see Supporting Data)

2. Total Electrical Savings (kwh/yr) would be the kw savings times the length (in hours) of the load shed operation period times the number of zones involved (assuming same HP for each zone).

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $20,000 up (see EMCS Cost Estimating Data (Report No. CR 83.008) available from the Naval Civil Engineering Laboratory at Port Hueneme)

Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Design engineers, installation technicians
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Equipment Life: 15 years
- Replacement Cost: Same as startup cost
- Startup Cost: $20,000
- Outside (ventilation) air intake is already at lowest possible value.
- HVAC system is divided into four large zones of approximately equal size, each of which has auxiliaries that would normally run constantly, but that if shut down will not adversely affect operation of the other zones.
- Each zone has a total of 20 horsepower of electrically driven auxiliaries that will be shut down on a rotational basis (one at a time) throughout the load shed period.
- Load Factor: 0.8 (see Supporting Data)
- Annual Hours When Demand Limiting Is in Effect: 200 hr/yr
- Change in O&M: $200/yr (increase)
- Fuel Saved: Electricity
- Energy Cost: $0.08 kwh
- Escalation Rate: 7%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Electrical Savings/Zone (kw/zone) =

20 hp x 0.8 x (0.746 kw/hp) x 0.25

= 2.98 kw/zone

ELECTRICAL SAVINGS (kwh/yr) =

2.98 kw/zone x 4 zones x 200 hours/yr

= 2,387 kwh/yr

NES (MBtu) =

(2,387 kwh/yr x 11,600 Btu/ kwh x MBtu/10^6 Btu)

= 27.69 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

2,387 kwh/yr x $0.08/kwh = $191/yr

SIR =

$$\frac{0 + \$191\ (18.049) + (-\$200)\ (9.524)}{\$20,000\ (1.251)}$$

= 0.1

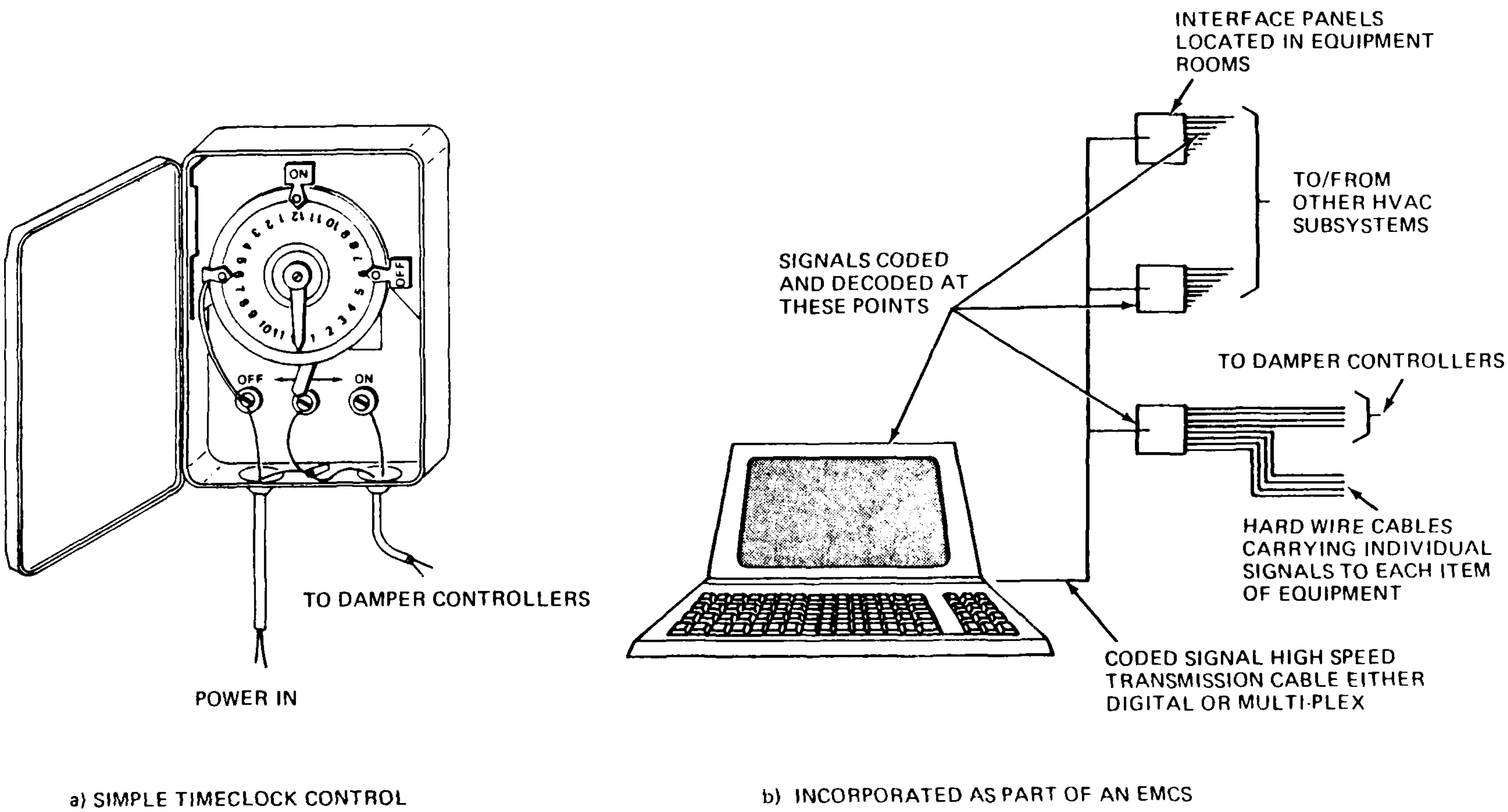
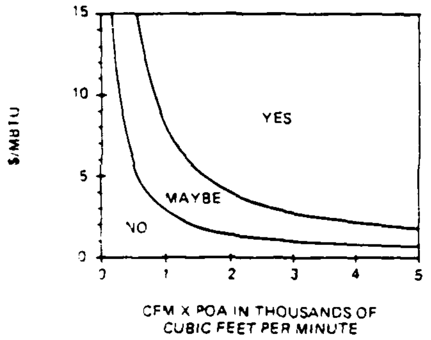


Figure HVAC-22. Ventilation Air Damper Control

HVAC 22. VENTILATION AIR DAMPER CONTROL

DESCRIPTION: The thermal load imposed by outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements for a facility. This ECO strategy involves control of the outside (i.e., the ventilation) air dampers so that outside air is introduced only during a building's occupied period plus a 15-minute purge period prior to occupancy). This strategy is applicable any time a building has significant unoccupied periods, even if environmental conditions must be maintained for proper operation of electronic equipment or for other reasons.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Cooling and heating energy savings are available for what is generally a low startup cost and insignificant increase in O&M costs.

SURVEY DATA NEEDS:

- HVAC systems(s) capacity in cubic feet per minute (CFM)
- Hours of normal operation per week (H)
- Average outside temperature(s) (°F)
- Cooling Energy Efficiency Ratio (EER)
- The ratio of outside air to return air used (POA)
- Warmup period length* (hr)
- Setpoint temperatures (°F)
- Heating Plant Efficiency (HEFF)

* Use either the actual time presently scheduled for warmup by existing timeclock, or average warmup time (if known) if optimized start/stop is employed, or use 2 hours as an estimate.

PROCEDURE: If scheduled or optimized start/stop HVAC control is already employed or planned, use equation (1) only (since the remainder of the savings represented by equations (2) and (3) are either already being realized, or are accounted for by ECOs 18 or 19). If start/stop operation is not now employed, and will not be employed, use equations (2) and (3), which include the savings of equation (1). These equations all assume a 15-minute purge of ventilation air is necessary prior to occupancy.

1. Fuel Savings (MBtu/yr) =

Warmup ventilation heating savings =

(CFM x POA x (WSP - AWT) x AND x

(WH - 0.25 hr/day) x (1.08 Btu/cfm°F-hr)) x

(1/(HEFF x 10^6 Btu/MBtu))

2. Fuel Savings (MBtu/yr) =

Ventilation heating savings =

(CFM x POA x (1.08 Btu/cfm°F-hr) x (WSP - AWT) x

(UH - (0.25 hr/day x DAY)) x WKW) x

(1/(HEFF x 10^6 Btu/MBtu))

3. Electrical Savings (kwh/yr) =

Ventilation cooling savings =

(CFM x POA x (4.5 lb/cfm-hr) x (OAH-RAH) x

(UH-(0.25 hr/day x DAY)) x WKS x 7) x

(1/(1,000 x EER))

where:

AND = Total Number of Days That Morning Warmup is Required in Days Per Year (see Supporting Data)
AWT = Average Winter Temperature in °F (see Supporting Data)
CFM = Air Handling Capacity in ft^3/min
DAY = Equipment Operation in Days Per Week
EER = Cooling Energy Efficiency Ratio in Btu/wh
HEFF = Heating Efficiency of the Total System, Including Converters, Transmission System, and Boilers (see Supporting Data)
OAH = Average Outside Air Enthalpy in Btu per pound (see Supporting Data)
POA = Present Percent Minimum Outside Air Expressed as a Decimal
RAH = Return Air Enthalpy During Unoccupied Hours. (Use 29.91 Btu/lb for 78°F and 50% humidity. For other conditions obtain values from a psychrometric chart.)
UH = Unoccupied Hours Per Week
WH = Present Morning Warmup Time Before Occupancy (Hr/Day) (Use either the actual time presently scheduled for warmup by an existing timeclock or 2 hours to correspond to scheduled start/stop savings calculations.)
WKW = Weeks of Winter Per Year (see Supporting Data)
WKS = Length of Summer Cooling Season in Weeks Per Year (see Supporting Data)
WSP = Winter Thermostat Setpoint Temperature in °F (normally 65°F)

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $500
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Design engineer, electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION: (See Supporting Data for explanation of variables.)

Assumptions:
- Heating Plant Efficiency HEFF: 75%
- Startup Cost: $500
- Air Handling Capacity (CFM): 10,000 ft^3/min
- Percent Minimum Outside Air (in decimal form): 0.10
- Winter Thermostat Setpoint Temperature (WSP): 68°F
- Average Winter Temperature (AWT): 45°F
- Total Number of Days that Require Morning Warmup: 130 days/yr
- Present Morning Warmup Time Before Occupancy (WH): 2 hours
- Scheduled start/stop scheme is already employed
- Change in O&M: None
- Fuel Saved: Gas
- Energy Cost: $6.00/MBtu
- Escalation Rate: 8%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

FUEL SAVINGS (MBtu/yr) =

Warmup ventilation heating savings = ES =

$$\frac{10,000 \times 0.1 \times (68 - 45) \times 130 \times (2 - 0.25) \times 1.08}{0.75 \times 10^6}$$

= 7.53 MBtu/yr

Procedure equations 2 and 3 are not applicable since, per assumptions, scheduled start/stop has already been employed.

NES (MBtu/yr) =

7.53 MBtu/yr

FUEL COST SAVINGS ($/yr) =

7.53 MBtu/yr x $6.00/MBtu = $45/yr

$$SIR = \frac{\$45.00\ (20.05) + 0 + 0}{\$500\ (1.251)}$$

= 1.4

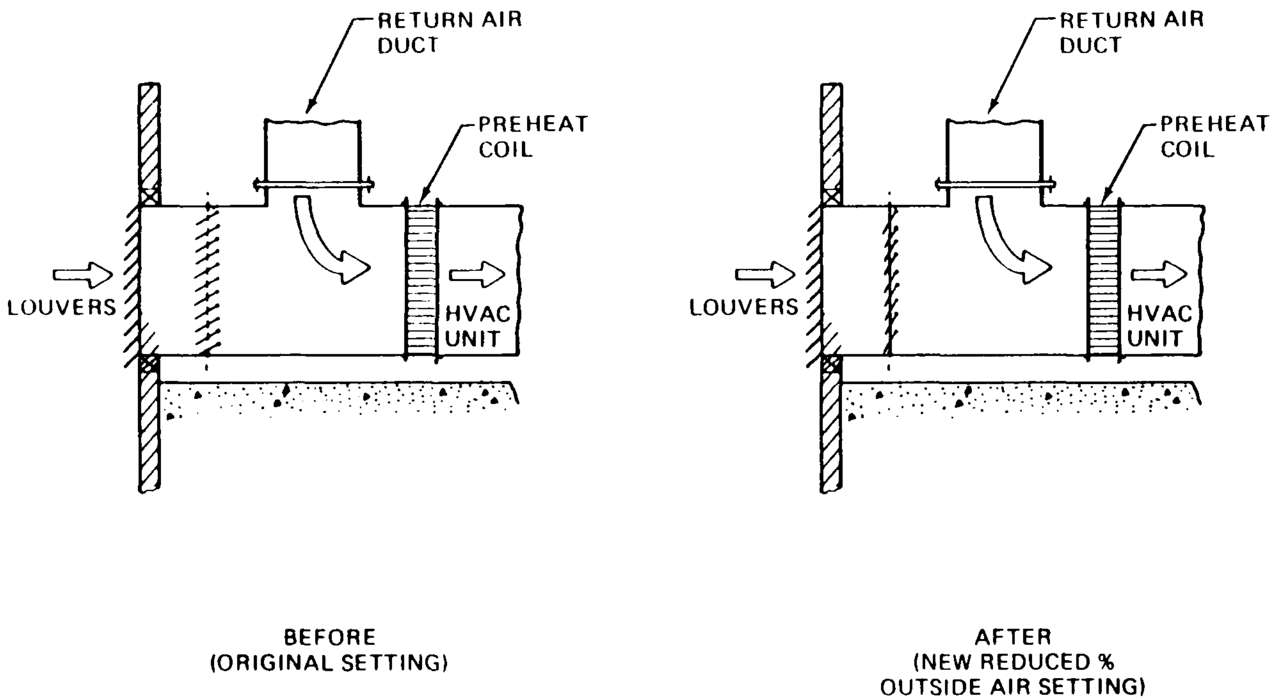
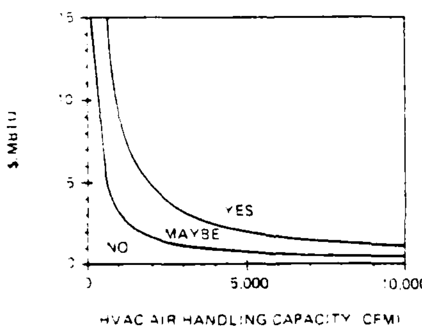


Figure HVAC-23. Resetting Outside Air Damper Opening

DESCRIPTION: Energy expended to heat or cool outside air brought in for ventilation constitutes a very significant percentage of the total HVAC energy costs. Therefore, the amount of outside air processed should be reduced to the minimum consistent with health and safety. In general there are three independent aspects to reducing the amount processed. Two of these (i.e., damper leakage, and damper open/close control scheduling) address savings possible during periods when ventilation air is not required. They are covered by ECOs HVAC 12 and 22. This ECO addresses the period when outside air is required.

Potential for savings often exists because many systems are set to meet a criteria for an amount of return air needed that is considerably in excess of the present day criteria of 5 to 10 cfm per person. Moreover, existing systems generally do not provide for more than one fixed open position setting. If, for example, a building has a significantly reduced occupancy load on a second shift, energy could be saved by resetting damper position at beginning of second shift to reduce the outside air intake to just that required by the reduced occupancy. Providing for more than one open setting, of course, will generally require some new or additional equipment (e.g., damper position limit switches, timeclocks, etc.). However, simply resetting the (single) open position usually involves no more than a small amount of one-time labor, with a continuing high return of energy savings.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Reducing the amount of outside air introduced for ventilation, if still sufficient for health and safety requirements, usually has no detrimental effects (although in a few situations extra outside air may be needed to avoid certain harmless but nevertheless unpleasant odors). When the outside air presently being introduced is well above what is really needed, considerable savings are possible because (depending on climate) outside air is generally quite expensive to process.

SURVEY DATA NEEDS:

- HVAC air handling capacity (CFM)
- Heating Energy Index (EIH) (see Supporting Data table SD2)
- Cooling Energy Index (EIC) (see Supporting Data table SD2)
- Occupancy situation (i.e., number of shifts, number of people per shift, etc.)
- Cooling Energy Efficiency Ratio (EER)
- Heating Plant Efficiency (HEFF)
- Operating hours per week during which the makeup (outside) air damper is open (HOD)
- Temperature of outside air (Tos) (°F)
- Temperature of return air (Trth) (°F)
- Temperature of mixed air entering the air handling unit (Tmix) (°F)

PROCEDURE: (See Glossary section for explanation of variables.)

1. Determine existing outside (ventilation) air to return air ratio using the following relationship:

$$POA_{ex} = \left[(T_{rtn} - T_{mix})/(T_{rtn} - T_{os})\right] \times 100\%$$

where:
T_{os} = Temperature of Outside Air in °F
T_{rtn} = Temperature of Return Air in °F
T_{mix} = Temperature of Mixed Air Entering the Air Handler Unit

2. Establish new POA value to be used (generally 5 to 10 cfm per person)

$$POA_{new} \ \frac{(\text{No. of persons} \times 7.5\ \text{cfm/person})}{\text{HVAC Air Handling Capacity}} \times 106$$

3. Fuel Savings (MBtu/yr) =

$(cfm/1{,}000\ cfm) \times EIH\ (Btu/yr) \times (HOD/(50\ hr/yr)) \times$

$(1/HEFF) \times (POA_{existing} - POA_{new}) \times (MBtu/10^6\ Btu)$

4. Electrical Savings (kwh/yr) =

$(cfm/1{,}000\ cfm) \times EIC\ (Btu/yr) \times (HOD/50\ hr/wk) \times$

$(12/EER\ (Btu/wh)) \times (kwh/1{,}000\ wh) \times 293$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $500
Replacement Cost: Same as startup cost
Equipment Life: 15 to 25 years
Skill Level of Personnel Required: Design engineer, electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{fuel}(DERF) + \Delta E_{elec}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Heating Plant Efficiency (HEFF): 75%
Startup Cost: $500
HVAC Air Handling Capacity: 10,000 ft^3/min
New POA is to provide 7.5 cfm per occupant
Building Occupancy: 150 people 1st shift, 5 days per week; unoccupied remainder of time
HOD: 8 hour per day plus 15 min preoccupancy purge time 5 days per week = 41.25 hours per week

Heating Energy Index (EIH): 45
Cooling Energy Index (EIC): 20
Cooling Energy Efficiency Ratio (EER) = 6.8
Air Temperature Data: $T_{rtn} = 68^oF$; $T_{mix} = 57^oF$ when $T_{os} = 35^oF$
Change in O&M: None
Equipment Life: 15 years
Replacement Cost: Same as startup cost
Fuel Saved: Gas and electricity
Energy Cost: \$0.08/kwh, \$6.00/MBtu
Escalation Rate: 7%, 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$POA_{ex} = \left[(68-57)/(68-35)\right] \times 100 = 33.3\%$

$POA_{new} = \left[(150 \text{ people} \times 7.5 \text{ cfm}) \times \times 100\right]/(10,000 \text{ ft}^3/\text{min}) = 11.25\%$

FUEL SAVINGS (MBtu/yr) =

(10,000/1,000) x (45) x (41.25/50) x (1/0.75) x

(0.3333 - 0.1125) = 109 MBtu

ELECTRICAL SAVINGS (kwh/yr) =

(10,000/1,000) x (20) x (41.25/50) x 12/6.8 x

(293) x (0.3333 - 0.1125) = 18,837 kwh

NES (MBtu/yr) =

109 MBtu/yr + (18,837 kwh/yr x 11,600 Btu/kwh)

= 328 MBtu/yr

FUEL COST SAVINGS (\$/yr) =

109 MBtu x \$6.00/MBtu = \$654/yr

ELECTRICITY COST SAVINGS (\$/yr) =

18,837 kwh x \$0.08/kwh = \$1,507/yr

SIR =

$$\frac{\$654\ (20.05) + \$1,507\ (18.049) + 0}{\$500\ (1.251)}$$

= 64

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HOT WATER

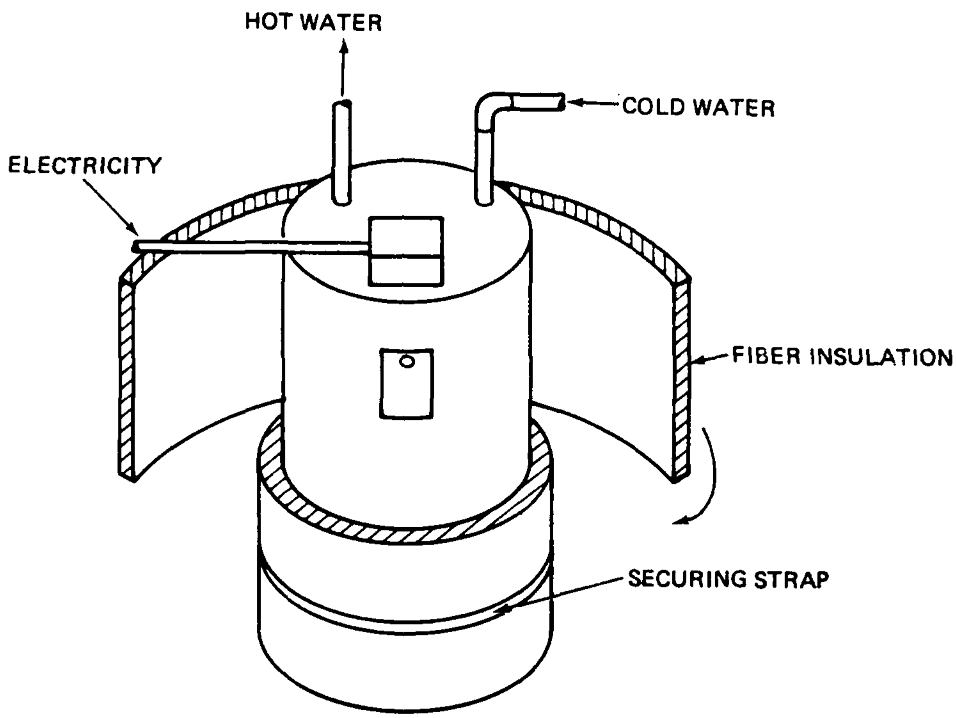
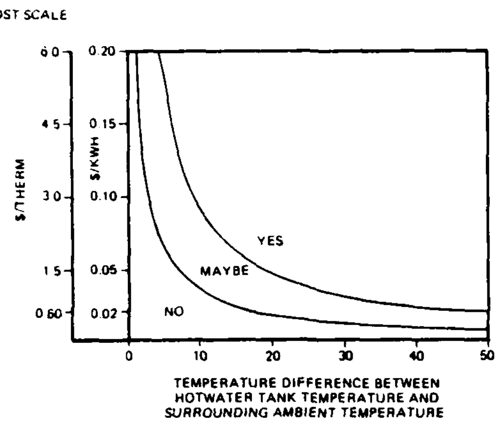


Figure HW-1. Insulate Hot Water Storage Tanks

HW 1. INSULATE HOT WATER STORAGE TANKS

DESCRIPTION: Hot water storage tanks employed in most domestic hot water systems must have heat added to offset losses to the surroundings while maintaining a readily available supply of hot water. While most tanks have some insulation, additional insulation can be added to reduce heat losses. Insulation should be selected in accordance with manufacturer's suggestions and code requirements.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Energy used to offset the hot water tank's heat losses can be reduced.

SURVEY DATA NEEDS:

- Number of uninsulated hot water tanks
- Surface area of tank
- Thickness and U-value of existing insulation
- *U-value of planned insulation*
- Ambient temperature of surroundings
- Hours of operation per year
- Hot water temperature

PROCEDURE:

1. Determine surface area of the tank, thickness and U-value of insulation (see table below), water temperature, and average surrounding temperature. Most older tanks have some insulation, typically 2-in. for electric types and 1-in. for gas types.

Insulation (Fiberglass Batt) (In.)	R Value	U-Value (1/R)
1	3.16	0.31
2	6.28	0.159
3-1/2	11.00	0.091
6	19.00	0.053

1a. $\text{U-Value}_{new} = \dfrac{1}{R_{old} + R_{new}}$

2. Fuel Savings (MBtu/yr) =

$$(\text{U-Value}_{old} - \text{U-Value}_{new})\ \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^o\text{F}} \times$$

$$\text{Surface Area (ft}^2) \times$$

$$(\text{Temp}_{water} - \text{Temp}_{surrounding}\ (^o\text{F})) \times$$

$$\frac{\text{Operating hr}}{\text{yr}} \times \frac{1}{\text{System Efficiency}}$$

where:

Efficiency = 0.75 for Gas
= 0.70 for Oil
= 0.95 for Electric

3. Electrical Savings (kwh/yr) =

$$(\text{U-value}_{old} - \text{U-value}_{new})\ (\text{Btu/hr-ft}^2\text{-}^o\text{F})$$

$$\times \text{ Surface Area (ft}^2)$$

$$\times\ (\text{Temp}_{water} - \text{Temp}_{surrounding}\ (^o\text{F}))$$

$$\times \text{ (Operating hr/yr)} \times \frac{1}{\text{system efficiency}}$$

$$\times \frac{\text{kwh}}{3{,}413 \text{ Btu}}$$

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost: \$2.00/ft^2 (2 in. thick)
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Insulation contractor, Maintenance staff
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\text{SIR} = \frac{\Delta E\ (\text{DERF}) + \Delta O\&M\ (\text{PYDF})}{C(\text{PIF})}$$

SAMPLE CALCULATION:

Assumptions:
Electric resistance heaters
Two tanks; 6 ft (h) x 2.5 ft (dia)
Insulation (old): 2 in
Insulation (new): 6 in. (total)
Water Temperature: 140^{o}F
Air Temperature: 70^{o}F
Operating hr/yr: 8,760
Startup Cost: \$278 (labor and materials)
Change in O&M: None
Fuel Saved: electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Tank Surface Area (ft^2) $= 2\pi rh + 2\pi r^2$*
$= 2(3.14)(1.25)(6) +$
2(3.14)(1.2 [illegible]
$= 56.91$ ft^2/Tank

Tank Surface Area (ft^2) for Two Tanks $= 113.82$ ft^2

ELECTRICAL SAVINGS (kwh/yr) =

$$(2)(0.159-0.053)\ \frac{\text{Btu}}{\text{hr-ft}^2\text{-}^o\text{F}} \times 56.91 \text{ ft}^2 \times$$

$$(140^o\text{F} - 70^o\text{F})(8{,}760 \text{ hr/yr}) \times \frac{1}{0.95} \times \frac{\text{kwh}}{3{,}413 \text{ Btu}}$$

= 2,282 kwh/yr

* $2\pi r^2$ is only for electrical heaters.

NES (MBtu/yr) =

(2,282 kwh/yr) (11,600 Btu/kwh x MBtu/10^6 Btu)

= 26 MBtu

ELECTRICITY COST SAVINGS ($/yr) =

(2,282 kwh) ($0.08/kwh) = $183/yr

$$SIR = \frac{\$183\ (18.049) + 0\ (9.524)}{\$278\ (1)}$$

= 11.9

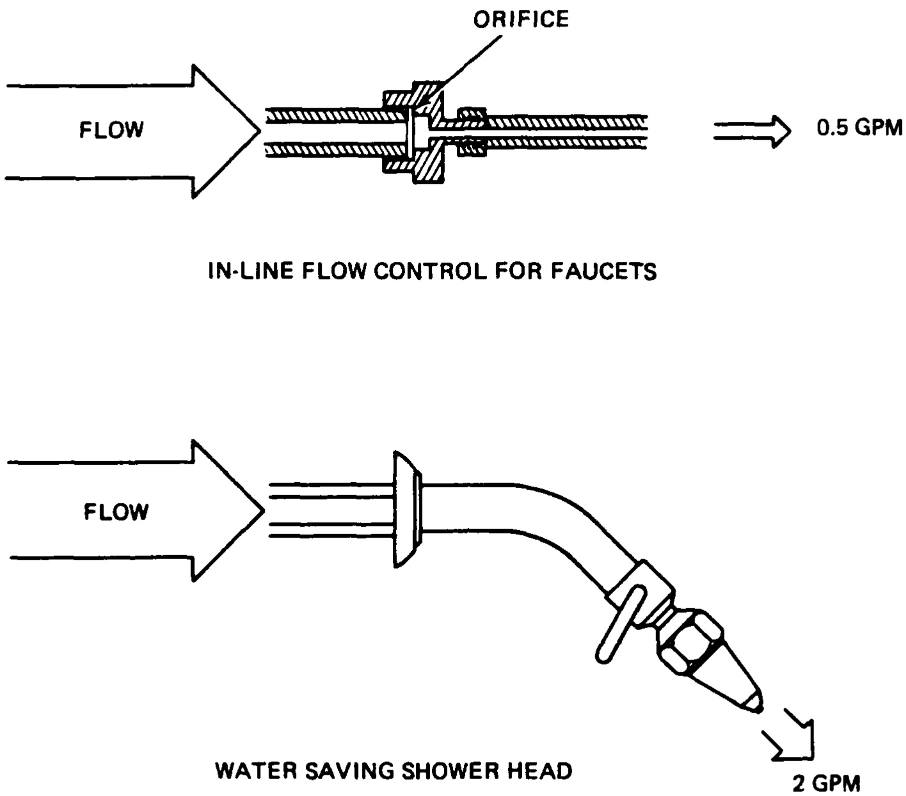
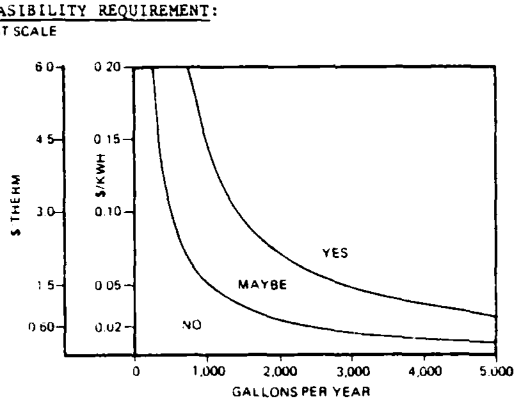


Figure HW-2. Install Water Flow Restrictors

HW 2. INSTALL WATER FLOW RESTRICTORS

DESCRIPTION: Water flow restrictors can be installed to limit the maximum flow rate a faucet or shower can deliver. The restrictors may either consist of a specially designed new faucet or shower head, or a small washer-like orifice placed in the hot water line near the point of use. Showers with flow rates above 3 gpm and sink faucets with flows greater than 1 gpm are attractive candidates. Do not install flow restrictors on wash sinks used in maintenance for filling buckets, etc.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: In addition to savings of water, energy costs associated with heating water may be reduced by as much as 50%. Potential user inconvenience.

SURVEY DATA NEEDS:

- Showers with flow rates above 3 gpm
- Single faucets with flow rates above 1 gpm (not including sinks for filling buckets, etc.)
- Hot water consumption per day
- Hot water temperature (°F)
- Amount of flow decrease due to restrictor (%)

PROCEDURE:

1. Determine hot water consumption. If data is not available, use the following for estimation:

   Office: 3 gallons/person/day
   Housing: 25 gallons/person/day
   Hospital: 40 gallons/person/day

2. Fuel Savings (MBtu/yr) =

   (Hot Water Temperature (°F) - Cold Water Temperature (°F))

   $\times \frac{8.3 \text{ lb}}{\text{gal}} \times \frac{1 \text{ Btu}}{\text{lb-}^\circ\text{F}} \times \frac{\text{gallons used}}{\text{yr}}$

   x % of Water Saved by Restrictors

   x 1/System Efficiency

   where:

   Efficiency = 0.75 for Gas
   = 0.70 for Oil
   = 0.95 for Electric

3. Electrical Savings (kwh/yr) =

   (Hot Water Temperature (°F) - Cold Water Temperature (°F))

   $\times \frac{8.3 \text{ lb}}{\text{gal}} \times \frac{1 \text{ Btu}}{\text{lb-}^\circ\text{F}} \times \frac{\text{gallons used}}{\text{yr}}$

   x % of Water Saved by Restrictors

   x 1/System Efficiency x kwh/3,413 Btu

GENERAL INFORMATION:

Sizes Available: Standard faucet and shower head sizes
Startup Cost: $15.00/valve-type unit
$ 5.00/orifice-type unit
Replacement Cost: Same as startup cost
Equipment Life: 10 years
Skill Level of Personnel Required: Maintenance staff
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Electric resistance water heater
156,000 gallons of water used/yr
50% of water saved by restrictors
Water Temperatures: Hot = 130°F, Cold = 60°F, Temperature Difference (Δt) = 70°F, 15 orifice type restrictors installed
Startup Cost = $75.00
Change in O&M: None
Fuel Saved: electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

$$(130^\circ F - 60^\circ F) \times \frac{8.3 \text{ lb}}{\text{gal}} \times \frac{1 \text{ Btu}}{\text{lb}^\circ F} \times 156{,}000 \text{ gal/yr}$$

$$\times 0.5 \times \frac{1}{0.95} \times \frac{\text{kwh}}{3{,}413 \text{ Btu}}$$

= 13,977 kwh/yr

NES (MBtu/yr) =

(13,977 kwh/yr) (11,600 Btu/kwh x MBtu/10^6 Btu)

= 162 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

(13,977 kwh/yr) ($0.08/kwh)

= $1,118/yr

$$SIR = \frac{\$1,118\ (18.049) + 0}{\$115\ (1.561)}$$

= 112.4

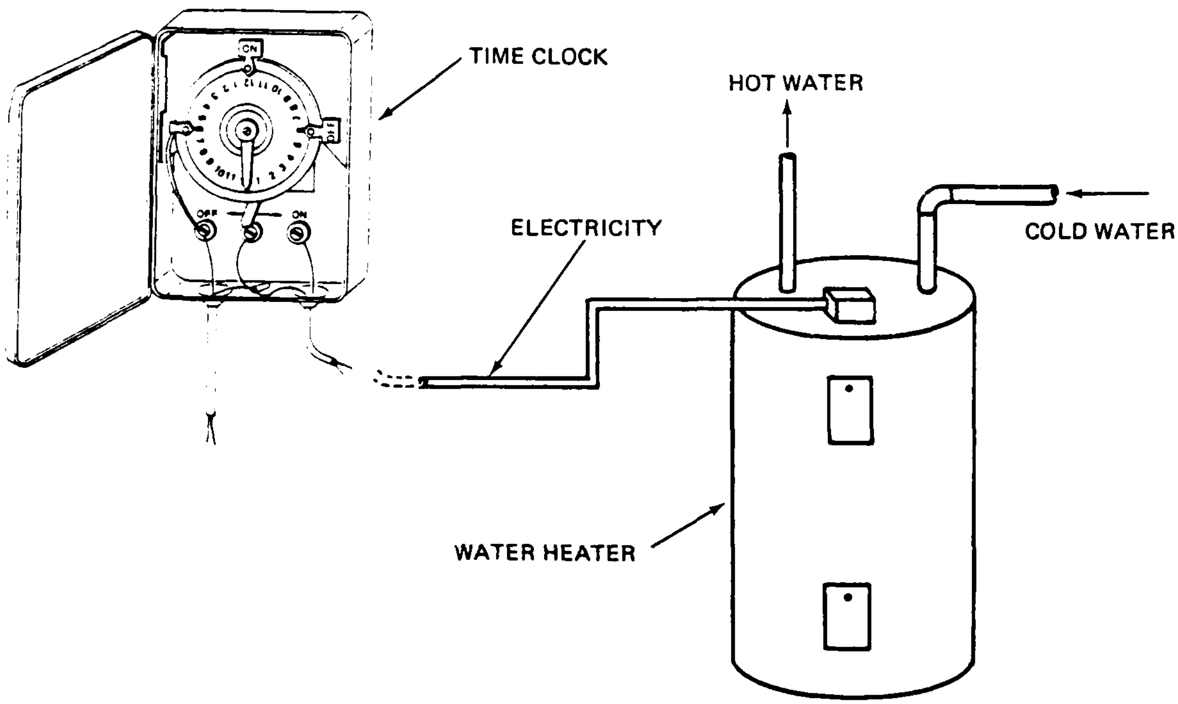


Figure HW-3. Install Time Clock on Heating Cycles

HW 3. INSTALL TIME CLOCK ON HEATING CYCLES

DESCRIPTION: When domestic hot water is consumed during well-defined periods of the day, time control units can be used to schedule water heaters. Heaters can be scheduled to operate just prior to a main period of hot water consumption and to turn off as the period tapers off. This mode of operation allows the storage tank temperature to drop during the period of low use and conserves energy that would otherwise be needlessly expended by losses.

FEASIBILITY REQUIREMENT:

NO	MAYBE	YES	NON-USAGE HOURS
7	9		

BENEFITS/DETRIMENTS: Through scheduling according to use, heat (energy) loss can be reduced.

SURVEY DATA NEEDS:

- Hot water demand schedule
- Tank height
- Tank diameter
- Insulation thickness (INS in inches)
- Ambient temperature
- Water operating temperature

PROCEDURE:

1. Calculate the surface area (ft^2) and volume (V) (ft^3) of the hot water tank.
2. Using Demand Schedule, determine the hours of non-use.
3. Determine the tank insulation thickness (INS) (inches).
4. Determine:

   T_s = Ambient Air Temperature (°F)

   T_o = Hot Water Temperature (°F)

5. a. Use nomograph 23 to determine the heat transfer effectiveness coefficient (E).

6. Fuel Savings (MBtu/yr) =

$$\Big[(\text{Tank Surface Area } (ft^2) \times (T_o - T_s) \times \text{Hours of Non-Use/Day} \times (0.285 \text{ Btu-in}/ft^2\text{-hr-}^{\circ}F)/\text{INS}) - (V\ ft^3 \times (62.4 \text{ Btu}/ft^3\ \text{hr-}^{\circ}F) \times (T_o - T_s) \times (1 - E))\Big] \times 365 \text{ days/yr} \times (1/\text{Heating Efficiency})$$

   where:

   Heating Efficiency = 0.75 for Gas
   = 0.70 for Oil
   = 0.95 for Electric

7. Electrical Savings (kwh/yr) =

$$\Big[(\text{Tank Surface Area } (ft^2) \times (T_o - T_s) \times \text{Hours of Non-Use/Day} \times (0.285 \text{ Btu-in}/ft^2\text{-hr-}^{\circ}F)/\text{INS}) - (V\ ft^3 \times (62.4 \text{ Btu}/ft^3\text{-}^{\circ}F) \times (T_o - T_s) \times (1 - E))\Big] \times 365 \text{ days/yr} \times (1/\text{Heating Efficiency}) (\text{kwh}/3{,}413 \text{ Btu})$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $100 timeclock, 24-hr/day, 7-day/week operation
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (YDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Electric Resistance Heater
Tank Dimensions: 6 ft high (H) x 2.5 ft diameter (D)
Shutdown Time: 8 hr/day
Insulation Thickness: 3 in.
Hot Water Temperature (T_o): 140°F
Ambient Temperature (T_s): 70°F
Heating Efficiency: 95%
Startup Cost: $100
Change in O&M: None
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Using nomograph 23 and the following equation determine "E" for step 5:

$$\text{Tank Area} = \pi/2\ D^2 + 3.14(D)(H)$$
$$= 1.571\ (2.5)^2 + \pi(2.5)(6)$$
$$= 56.92\ ft^2$$

Tank volume = $\pi/4\ D^2H$

$= 0.785\ (2.5)^2\ (6)$

$= 29.44\ ft^3$

Compute the energy savings for two tanks (step 6):

ELECTRICAL SAVINGS (kwh/yr) =

$\Big[((56.92\ ft^2) \times (140^oF - 70^oF) \times (8\ hr) \times$

$\dfrac{0.285\ (Btu\text{-}in/ft^2hr\ ^oF))}{3\ in.} -$

$((29.44\ ft^3) \times (62.4\ Btu/ft^3\text{-}^oF)$

$(140^oF - 70^oF) \times (1 - 0.98))\Big] \times (365\ \dfrac{\text{shutdown periods}}{yr})$

$\div (0.95 \times 3{,}413\ Btu/kwh)$

$= 51\ kwh/yr$

NES (MBtu/yr) =

$0 + (51\ kwh/yr)\ (11{,}600\ Btu/kwh \times MBtu/10^6\ Btu)$

$= 0.60\ MBtu$

ELECTRICITY COST SAVINGS ($/yr) =

$(51\ kwh/yr)\ (\$0.08/kwh)$

$= \$4.08/yr$

$SIR = \dfrac{\$4.08/yr\ (18.049)}{\$100\ (1.251)}$

$= 0.59$

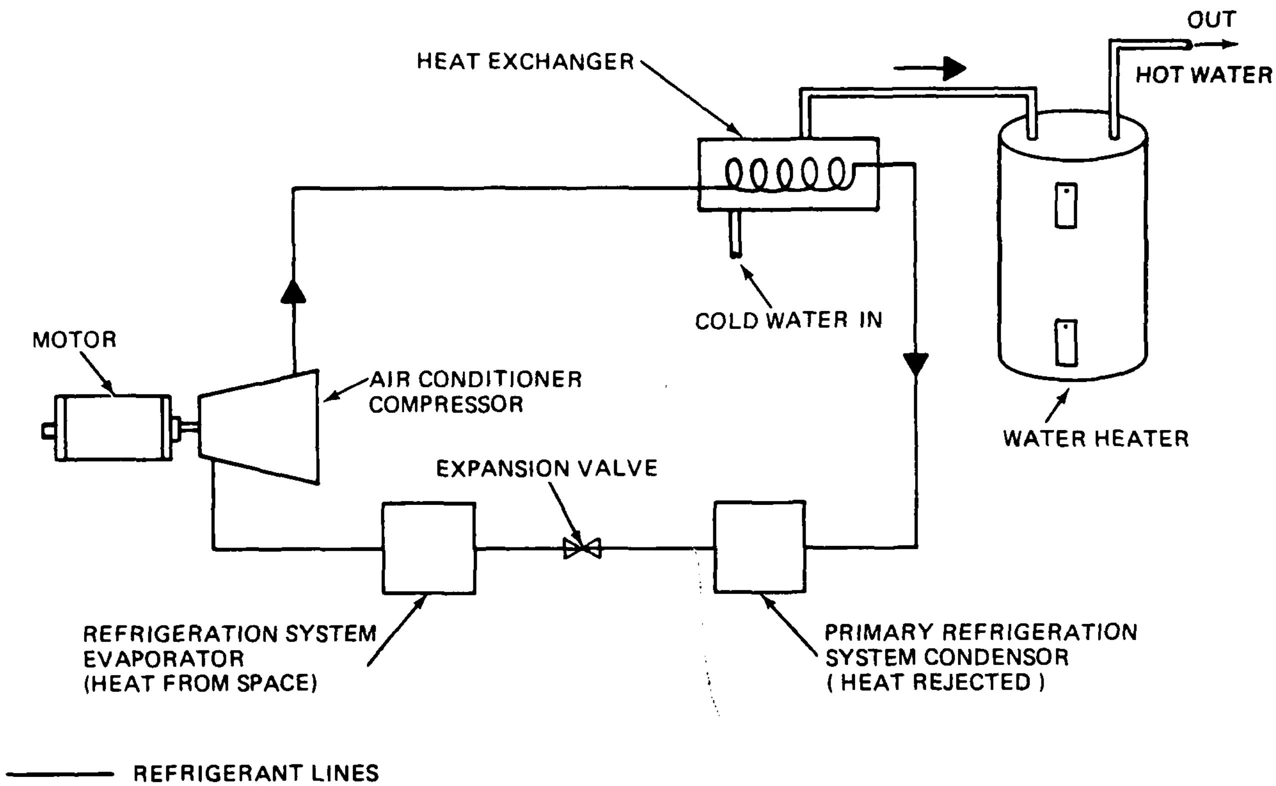


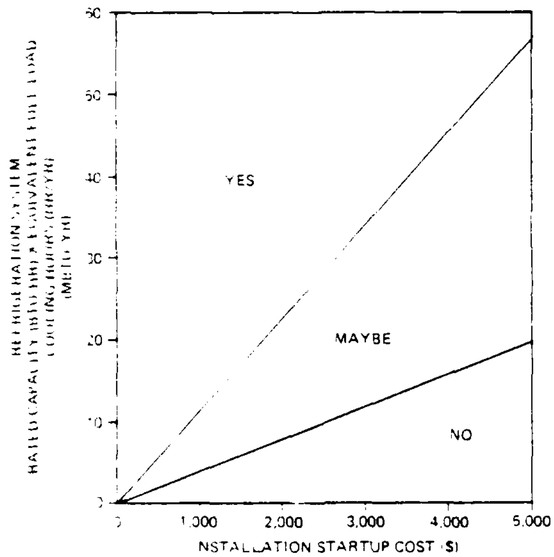
Figure HW-4. Use Regrigeration Waste Heat for Water Heating

HW 4. USE REFRIGERATION WASTE HEAT FOR WATER HEATING

DESCRIPTION: Waste heat from refrigeration equipment can be used to heat or at least preheat water feeding domestic water heaters. The amount of heat recovered and temperature to which the water can be warmed will vary from site to site. Additional engineering assistance may be required to evaluate the feasibility of the option.

(Waste heat may also be obtained from boiler flue gases, chillers, hot condensate, and heat from hot waste water).

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: While the equipment required is usually costly, the free energy source can make the options economically attractive. Excessive heat removal may jeopardize operation of heat source equipment.

SURVEY DATA NEEDS:

- Identify waste heat sources
- Full load cooling hours for area
- Determine rated cooling capacity of vapor compression refrigeration (Btu/hr)

PROCEDURE:

1. Determine rated cooling capacity in Btu/hr of the vapor compression refrigeration system.

2. Find the number of full load cooling hours for your site. See Supporting Data (table SD2) or determine from site records.

3. Fuel Savings (MBtu/yr) (for gas or oil water heaters only) =

   (Refrigeration System Rated Capacity (Btu/hr) x

   Equivalent Full Load Cooling Hours (hr/yr) x

   Recovery Factor*)/0.75

4. Electrical Savings (kwh/yr) =

   Refrigeration System Rated Capacity (Btu/hr) x

   Equivalent Full Load Cooling Hours (hr/yr) x

   Recovery Factor* x (1 kwh/3,413 Btu)/0.95

*(Recovery factor is dependent on proposed heat exchanger specified. If no better value is available, use 0.4 for Recovery Factor.)

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost: $1,700 to $3,100
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Plumber, air conditioning contractor
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Capacity: 60,000 Btu (5-ton) refrigeration unit
Equivalent Full Load Cooling hours: 1,000 hr/yr (from operating records)
Recovery Factor: 0.4
Startup Cost: $2,800
Change in O&M: $50/yr (increase)
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Capacity for 5-ton unit (Btu/hr) =

$$5 \text{ tons} \times \frac{12{,}000 \text{ Btu}}{\text{ton hr}}$$

$$= 6 \times 10^4 \frac{\text{Btu}}{\text{hr}}$$

ELECTRICAL SAVINGS (kwh/yr) =

$$6 \times 10^4 \text{ (Btu/hr)} \times 1{,}000 \text{ (hr/yr)} \times 0.4 \times$$

$$\frac{1 \text{ kwh}/3{,}413 \text{ Btu}}{0.95} (1/0.95)$$

= 7,402 kwh/yr

NES (MBtu/yr) =

$0 + (14{,}804 \text{ kwh/yr}) (11{,}600 \text{ Btu/kwh} \times \text{MBtu}/10^6 \text{ Btu})$

= 86 MBtu

ELECTRICITY COST SAVINGS (\$/yr) =

(7,402 kwh/yr) (\$0.08/kwh)

= \$592/yr

$$SIR = \frac{\$592/yr\ (18.049) + (-\$50)\ (9.524)}{\$2,800\ (1)}$$

= 3.6

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LIGHTING

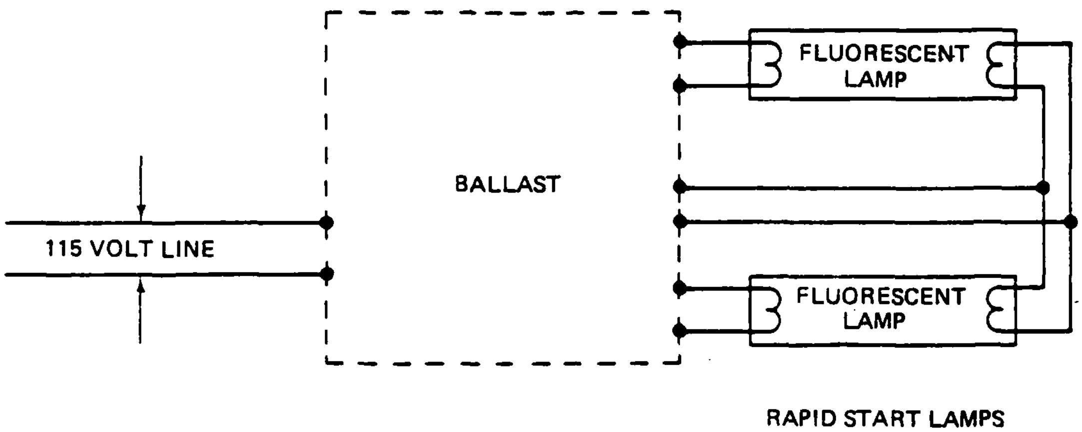
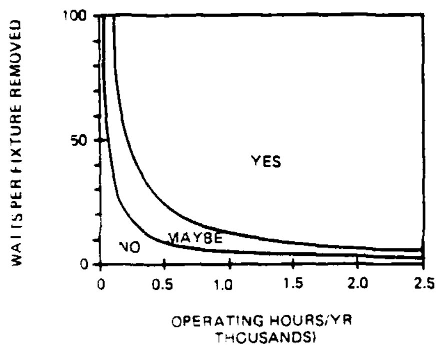


Figure L-1. Remove Lamps or Fixtures

L 1. REMOVE LAMPS OR FIXTURES

DESCRIPTION: Removing lamps and fixtures can conserve energy. When removing lamps from fluorescent fixtures, the ballasts should also be disconnected. They generally account for 10 to 15 percent of the fixture's power draw and will continue to consume energy after removing the lamps, though at a lower rate. Typically, one ballast serves two lamps. To maintain adequate lighting levels, higher output lamps may have to be substituted for some of the remaining lamps, but generally a net savings will result. In addition to the maintenance of adequate lighting intensities, consideration should be given to the quality of light supplied, as well as light placement. (Options L 1-4 should be reviewed prior to energy survey due to interrelationship of options.)

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: In situations when it is possible to take a percentage of fixtures out of service and still maintain adequate light levels, removal represents a very cost effective way to reduce energy consumption.

SURVEY DATA NEEDS:

- Required illumination for space(s)
- Existing illumination of space(s) (measured with light meter)
- Determine the lamp/fixture operating hours per year per room
- Watts per lamp/fixture
- Area of each space
- Lumens per lamp/fixture (see table 13 in tables section)
- Coefficient of utilization (see table 11 in tables section)
- No. of lamps per space

PROCEDURE:

1. Determine the current illumination (in footcandles) in each room, using a photometer.

2. Determine the minimum acceptable lighting level (in footcandles) for each room, using table 8 (tables section) as a guide.

3. Calculate the number of lamps to be removed in each space:

   Number of lamps to be removed =

   $$\left[(\text{Existing - Desired Illumination in Footcandles}) \times (\text{Area in ft}^2)\right] / \left[(\text{Lumens Per Fixture}) \times (\text{CU}) \times (\text{LLF})\right]$$

   where:

   CU = Coefficient of Utilization (typical value = 0.62. For additional values consult table 11.)

   LLF = Light Loss Factor (typical value = 0.65)

4. Using table 9 in tables section (or other appropriate data), determine the number of watts saved for each lamp removed. If ballasts are removed, add 10 to 15 percent of 2 lamp input wattage for each ballast removed. Also see L-4.

5. Electrical Savings (kwh/yr)/Space =

   $$\left[\left((\text{Number of lamps removed}) \times \frac{\text{watts}}{\text{fixture}}\right) + (\text{Number of ballasts removed}) \times (\text{watts/ballast})\right] \times \left[\frac{\text{hours of Operation}}{\text{year}} \times \frac{1\ \text{kw}}{1{,}000\ \text{watts}}\right]$$

6. To determine total annual electrical savings, multiply number of spaces by electrical savings per space.

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $7 to $12/labor per fixture disconnected
Replacement Cost: N/A
Equipment Life: 25 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\text{SIR} = \frac{\Delta E\ (\text{DERF}) + \Delta O\&M\ (\text{PYDF})}{C(\text{PIF})}$$

SAMPLE CALCULATION:

Assumptions:

Startup Cost: $28
CU: 0.60
LLF: 0.593
Lumens/Lamp: 3,300
Room Area: 560 ft^2
Current Illumination: 25 footcandles
Desired Illumination: 15 footcandles
Hours of Operation/Year: 2,500
Watts/Lamp: 40
Change in O&M: Negligible
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Number of Lamps to Remove =

$$\frac{(25 - 15\ \text{ft-can})(560\ \text{ft}^2)}{(3{,}300\ \text{lumens})(0.60)(0.593)}$$

= 4.8 lamps

Watts Saved by Removing 4 Lamps and 2 ballasts

= 184 watts

ELECTRICAL SAVINGS (kwh/yr) =

$$(184 \text{ watts}) \times 2{,}500 \frac{\text{hr}}{\text{yr}} \times \frac{1 \text{ kw}}{1{,}000 \text{ watt}} = 460 \text{ kwh/yr}$$

NES (MBtu/yr)

= (460 kwh/yr x 11,600 Btu/kwh) (MBtu/10^6 Btu)

= 5.34 MBtu/yr

ELECTRICITY COST SAVINGS (\$/yr) =

(460 kwh/yr) x (\$0.08/kwh) = \$37/yr

SIR =

$$\frac{(\$37/\text{yr})(18.049)}{(\$28)}$$

= 24

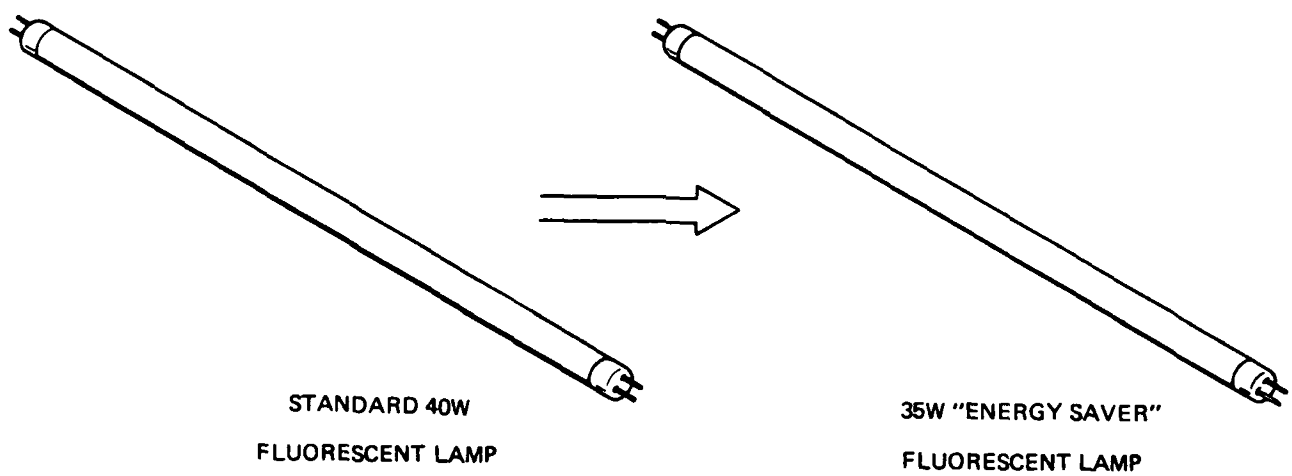


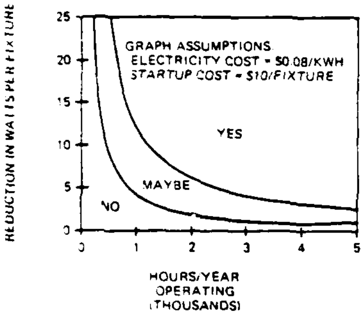
Figure L-2. Replace Lamps with Lower Power Requirement Types

L 2. REPLACE LAMPS WITH LOWER POWER REQUIREMENT TYPES

DESCRIPTION: Research resulting from concern over rising energy costs has resulted in a variety of new lamps available designed to reduce energy consumption. Reduction in power input requirement may be a result of increased lamp efficacy (lumens per watt), simply reduced wattage size (with no improvement in efficacy), or a combination of both. Regardless of how power requirement is reduced, consideration should be given to lamp replacement whenever lamps with reduced input wattage are available and will still provide adequate light level.

The replacement of standard 40-watt rapid-start fluorescent lamps with 34-watt "energy saver" types is used in this ECO as an example, but is just one case in point. Consult table 12 (table section) for other possibilities. Also consult ECO L 3 for addition of efficient lenses to increase lighting.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Energy consumed for lighting will be reduced. Levels of illumination may be reduced. Careful consideration should be given to the effects of the reduced illumination. In many cases the lower levels of illumination may still be more than adequate for the intended purpose, and can be implemented with a minimum of occupant dissatisfaction.

SURVEY DATA NEEDS:

- Required illumination for space(s) (see table 8 in tables section)
- Wattage of existing and new lamps
- Operating hours per year per lamp
- Number of lamps to be replaced with lower wattage types

PROCEDURE:

1. Refer to table 8 in tables section to determine required illumination for task(s). With light meter determine existing illumination of space(s) to verify that it meets or exceeds requirements.
2. Electrical Savings (kwh/yr)/Space =

   [watts/lamp (existing) - watts/lamp (new)] x (No. of lamps) x (1 kw/1,000 w) x (hours operation/yr)
3. To determine total annual electrical savings, multiply number of spaces by electrical savings per space.

GENERAL INFORMATION:

Sizes Available: See table 12
Startup Cost: \$2.00 to \$2.65 (4 ft 34-w tube)
\$4.00 to \$5.35 (8 ft 60-w tube)
\$7 to \$12 (labor)
Replacement Cost: Same as startup cost
Equipment Life: 20,000 hours
Skill Level of Personnel Required: Maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
100 Lamps Replaced: old wattage = 40w; new wattage = 34 w
No ballast change
2,500 hours/yr lamp operation
Startup Cost: \$900
Change in O&M: Negligible
Fuel Saved: Electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

$$\left[40\ \frac{watts}{Lamp} - 34\ \frac{watts}{Lamp}\right] \times 100\ \text{Lamps Installed} \times \frac{1\ kw}{1{,}000\ watt} \times \frac{2{,}500\ \text{hr Operation}}{yr}$$

= 1,500 kwh/yr

NES (MBtu/yr) =

0 + (1,500 kwh/yr x 11,600 Btu/kwh) x MBtu/10^6 Btu

= 17.4 MBtu/yr

ELECTRICITY COST SAVINGS (\$/yr) =

1,500 kwh/yr x \$0.08/kwh = \$120/yr

SIR =

$$\frac{\$120/yr \times (18.049) + 0}{\$900 \times (1.561)}$$

= 1.54

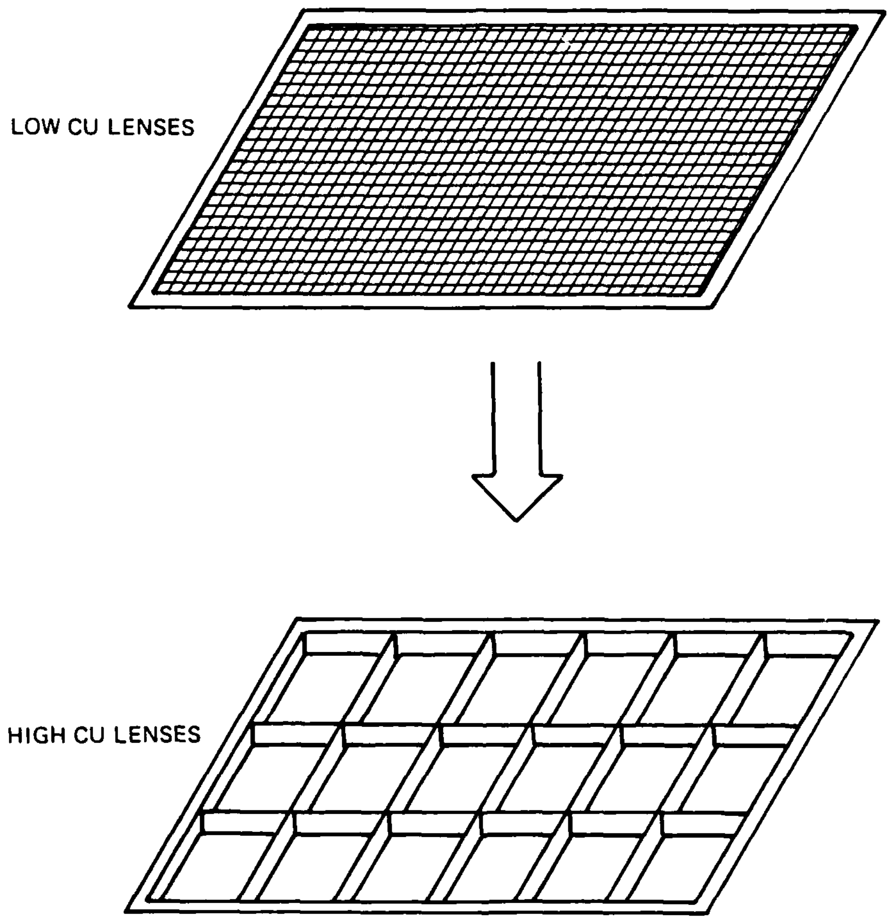


Figure L-3. Install More Efficient Lenses

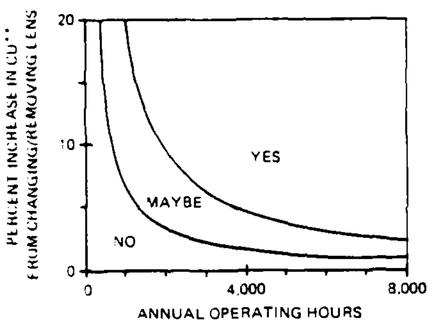
L 3. INSTALL MORE EFFICIENT LENSES

DESCRIPTION: Lenses are generally provided on lighting fixtures to reduce glare. Unfortunately this also reduces the amount of usable light. This is indicated by the fixture's coefficient of utilization (CU = ratio of lumens received on the work plane to the lumens emitted by the lamps alone.) The CU can be raised by using more efficient lenses, or by removing lenses where glare control is not required (corridors, restrooms). This may increase the level of illumination beyond Navy lighting requirements. Lighting may then be reduced to the required level to achieve energy savings. This can be accomplished through use of lower wattage/energy efficient lamps, (see ECO L-2) delamping, removing fixtures, or using dimmers.

FEASIBILITY REQUIREMENT:

Existing Lens	Suggested Replacement Lens			
	parabolic	prismatic	white	no lens
	Typical Increase in CU			
Parabolic	0	-15*	-30*	10
Prismatic	15	0	-20*	30
White	30	20	0	50
No Lens	-10*	-30*	-50*	0

* Negative values indicate decreased lumen efficiency



**Illumination varies directly as the coefficient of utilization (CU). Because of certain limitations, such as the fact that lamps are manufactured only in discrete sizes, the full advantage in power reduction corresponding to the CU increase is not generally possible. The graph assumes advantage can be taken of 75% of the CU increase.

BENEFITS/DETRIMENTS: More usable light can be obtained from the same wattage fixture, thus providing for reductions in lamp wattage or number used. Removal of lenses or replacement of existing lenses with less light loss will generally be accompanied by an increase in glare.

SURVEY DATA NEEDS:

- Existing illumination of space(s) (measured with light meter)
- Required illumination for space(s)
- Type of existing lens
- Existing lighting input power requirement (per fixture)
- Annual operating hours

PROCEDURE:

1. With light meter, determine existing space illumination level to verify that it meets or exceeds requirements.

2. Determine type of existing lens.

3. Determine existing lighting power requirement (per fixture) via direct measurement or using manufacturer's data.

4. Using the Feasibility Requirement Table, determine illumination change (ΔI) for replacing existing lens with new lens.

5. While maintaining lighting at present level (watts) compute power reduction as follows:

$$\Delta P = P_p \times \frac{\Delta I}{100 + \Delta I}$$

where:

ΔI = Change in illumination
P_p = Existing input power requirement (per fixture) (in watts)

6. Maximum Potential Electrical Savings (kwh/yr) =

ΔP x 1/1,000 x operating hours/yr x number of fixtures

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost: \$6 to \$15 lens and \$5 to \$7 labor
\$2 to \$5 4-ft lamp 2 to 5
\$4 to \$12 8-ft lamp
\$7 to \$12 labor to disconnect/install
Replacement Cost: Same as startup cost
Equipment Life (lens): 25 years
Skill Level of Personnel Required: Maintenance staff
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Startup Cost: \$10/fixture
100 fixtures (P_p) @ 175 watts
Lens to be removed (vice replaced)
Full advantage can be taken of any CU increase.
ΔI = 20%
Operating Hours: 2,600/year
Change in O&M: None
Fuel Saved: Electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ΔI = 20%

$$\Delta P = 175 \times \frac{20}{100 + 20} = 29.2 \text{ watts}$$

ELECTRICAL SAVINGS (kwh/yr) =

$$29.2 \text{ w} \times \frac{\text{kw}}{1{,}000 \text{ W}} \times \frac{2{,}600 \text{ hr}}{\text{year}} \times 100 \text{ fixtures}$$

= 7,592 kwh/yr

NES (MBtu/yr) =

2 (7,592 kwh/yr x 11,600 Btu/kwh)

= 88 MBtu

ELECTRICITY COST SAVINGS ($/yr) =

7,592 kwh/yr x $0.08/kwh

= $607/yr

SIR =

$$\frac{\$607\ (18.049) + 0}{\$1{,}000\ (1)}$$

= 10.96

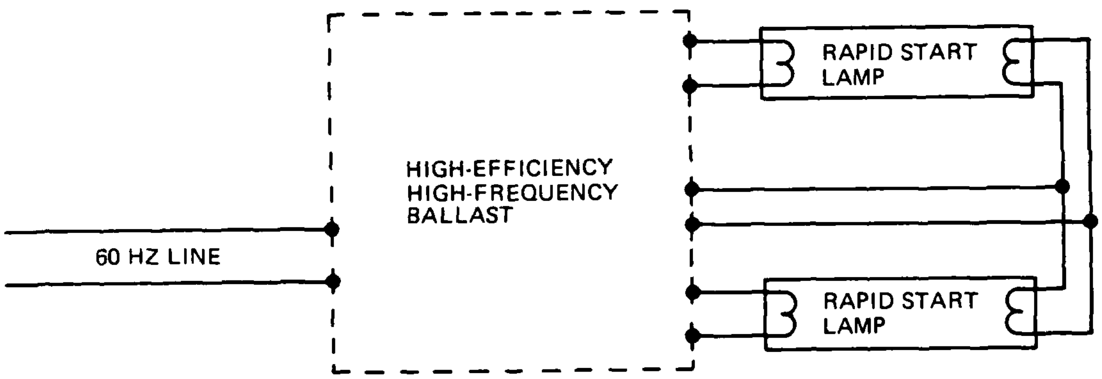


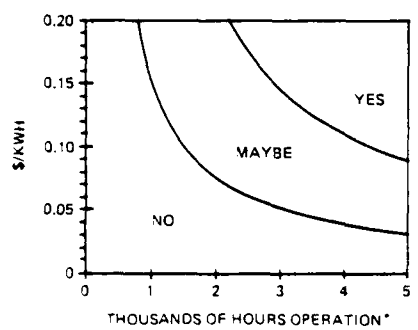
Figure L-4. Install More Efficient Ballasts

L 4. INSTALL MORE EFFICIENT BALLASTS

DESCRIPTION: The efficacy (lumens per watt) of fluorescent lamps increases as the frequency of impressed voltage increases. Energy conserving ballasts are now available that are more efficient inasmuch as the ballast itself has lower losses (dissipates less heat), and more significantly, because it allows the lamps to operate at a frequency (typically around 30 kHz) at which the lamp efficacy is much improved. These ballasts are generally referred to as "solid state" or "high frequency" due to the fact they use solid state electronics to convert the 60-Hz line frequency to the new (higher) lamp driving frequency. Since operating frequencies are beyond the audible range, quietness is an added benefit of this type ballast.

High-frequency ballasts are on the market that (for two 40-watt lamp applications) increase efficacy by 30 percent. The combined effect of improved lamp efficacy and ballast loss reduction can result in a 20-percent input power reduction (for same light output), compared with the standard line frequency ballasts of the past.

FEASIBILITY REQUIREMENT:



*BASED ON REPLACEMENT OF CONVENTIONAL BALLASTS WITH SOLID STATE BALLASTS.

Graph Assumptions:
- Total Startup Costs Per Fixture: $35
- Change in O&M Costs: None
- Watts Saved Per Fixture (typical of a two-F40T12/RS-tube fixture): 22

BENEFITS/DETRIMENTS: Electric energy consumption can be reduced with little or no adverse effect on illumination provided. Some reduction in the amount of heat dissipated can be expected and possibly a reduction in maintenance due to cooler operation, resulting in fewer ballast replacements over equal time. Air cooling requirements will be reduced (although additional air heating may be needed during the heating season).

Lamp fixture energy consumption can be even further reduced if, along with ballast replacement, the lamps themselves can be replaced with lower wattage units. Two 34-watt F40 tube replacements driven by an efficient high-frequency ballast can be operated at a 30-percent reduction in fixture power, as compared with standard 40-watt tubes and a conventional line frequency ballast, while reducing light output less than 10 percent.

SURVEY DATA NEEDS:

- Determine number of fixtures using conventional ballasts
- Determine average annual operating hours
- Sizes (wattage) and number of ballasts per fixture
- Input power for present ballast and tube combination
- Input power requirement for selected replacement ballast/tube combination

PROCEDURE:

1. Electrical Savings Per Year Per Fixture (kwh) =

$$\left(\begin{array}{l}\text{Number of Ballasts}\\ \text{Per Fixture Replaced}\end{array}\right) \times (\text{watts/Ballast}_{old} - \text{watts/Ballast}_{new})^{**} \times \frac{\text{kw}}{1{,}000\ \text{w}} \times \frac{\text{Oper hr}}{\text{year}}$$

**Use input power (i.e., ballast plus lamp load).

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost: $35 per two tubes ($17.50 material, 17.50 labor)
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E\ (\text{DERF}) + \Delta O\&M\ (\text{PYDF})}{(\text{PIF})}$$

SAMPLE CALCULATION:

Assumptions:
- Existing lamp and ballast combination: 92 watts
- New lamp and ballast combination: 84 watts
- Electrical savings: one ballast per fixture
- Operating hours: 2,500/yr
- Startup Cost: $35.0
- Change in O&M: None
- Fuel Saved: electricity
- Energy Cost: $0.08/kwh
- Escalation Rate: 7%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

$$\frac{92 - 84}{\text{fixture}} \times \frac{2{,}500\ \text{hr}}{\text{year}} \times \frac{\text{kwh}}{1{,}000\ \text{wh}}$$

= 20 kwh/fixture-year

NES (MBtu/yr) =

0 + (20 kwh/fixture-yr x 11,600 Btu/kwh)

= 0.232 MBtu/fixture-yr

ELECTRICITY COST SAVINGS ($/yr) =

20 kwh/fixture-yr x $0.08/kwh

= $1.6/fixture-yr

SIR =

$$\frac{\$1.6\ (18.049) + 0}{\$35\ (1.251)}$$

= 0.66

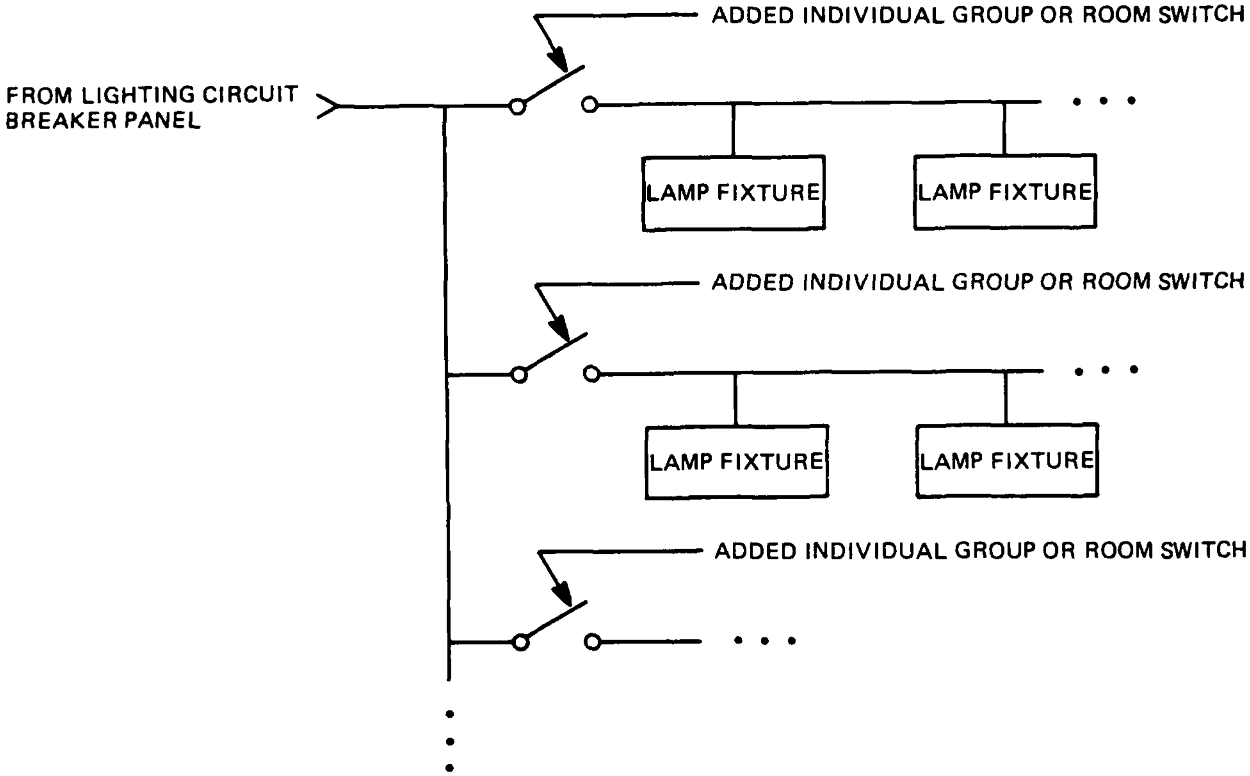
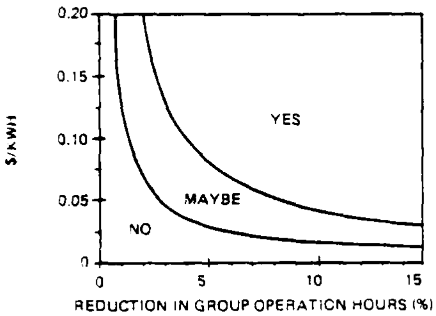


Figure L-5. Install Switching

L 5. INSTALL SWITCHING

DESCRIPTION: By installing additional switching which allows the control of lighting in smaller blocks, energy can be saved. Proper location of switches would permit lights in unoccupied areas or in areas near windows not requiring artificial light to be turned off. Lighting of high traffic areas could be operated separately in individual office spaces to accommodate varying work schedules. (Photocells which sense area lighting levels and time clocks can also be employed.)

FEASIBILITY REQUIREMENT:



Graph Assumptions:

Startup Cost (material + labor): $200
Fixtures Per Switch (Group): 15
Power Required Per Fixture: 175 watts
Preswitch Installation Operating Time: 50 hours per week: 52 weeks per year
Negligible O&M Costs

BENEFITS/DETRIMENTS: Selective control of lights by group (zone) permits turning off lights - thus saving energy - whenever available daylight and/or zone usage makes electric lighting unnecessary.

SURVEY DATA NEEDS:

- Determine occupancy/use patterns
- Determine the existing average annual operating hours
- Determine input power per fixture
- Determine light fixtures that need not be operated with the same pattern as other fixtures
- Determine the probable percent reduction in fixture operating time

PROCEDURE:

1. Input Power Per Switch (kw) =

   $\frac{\text{Power Requirement}}{\text{Fixture}} \times \frac{\text{No. Fixtures}}{\text{Switch}}$

2. Electrical Savings per Switch (kwh/yr) =

   Group Input Power (kw) x Oper. Time Red'n (hr)

3. Calculate total annual electrical energy savings (kwh) by summing annual savings of each individual switch.

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $200/switch
Replacement Cost: $20/switch replacement
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician

Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

Startup Cost: $200
Fixtures Per Switch: 15
Power Requirement Per Fixture: 175 watts
Operating Hours: 50 hr per week, 52 weeks per year
Average Operating Time Reduction With Switching: 5%
Replacement Life: 15 years
Change in O&M: None
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

INPUT POWER (kw) =

175 w/fixture x 15 fixtures x kw/1,000 w = 2.63 kw

ELECTRICAL SAVINGS (kwh/yr) =

2.63 kw x 50 hr/wk x 52 wk/yr x 5% = 342 kwh/yr

NES (MBtu/yr) =

342 kwh/yr x 11,600 Btu/kwh x (MBtu/10^6 Btu) =

3.96 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

342 kwh/yr x $0.08/kwh = $27.4/yr

$$SIR = \frac{\$27.4\ (18.049) + \$0(9.524)}{\$200\ (1.251)}$$

$$= 2.0$$

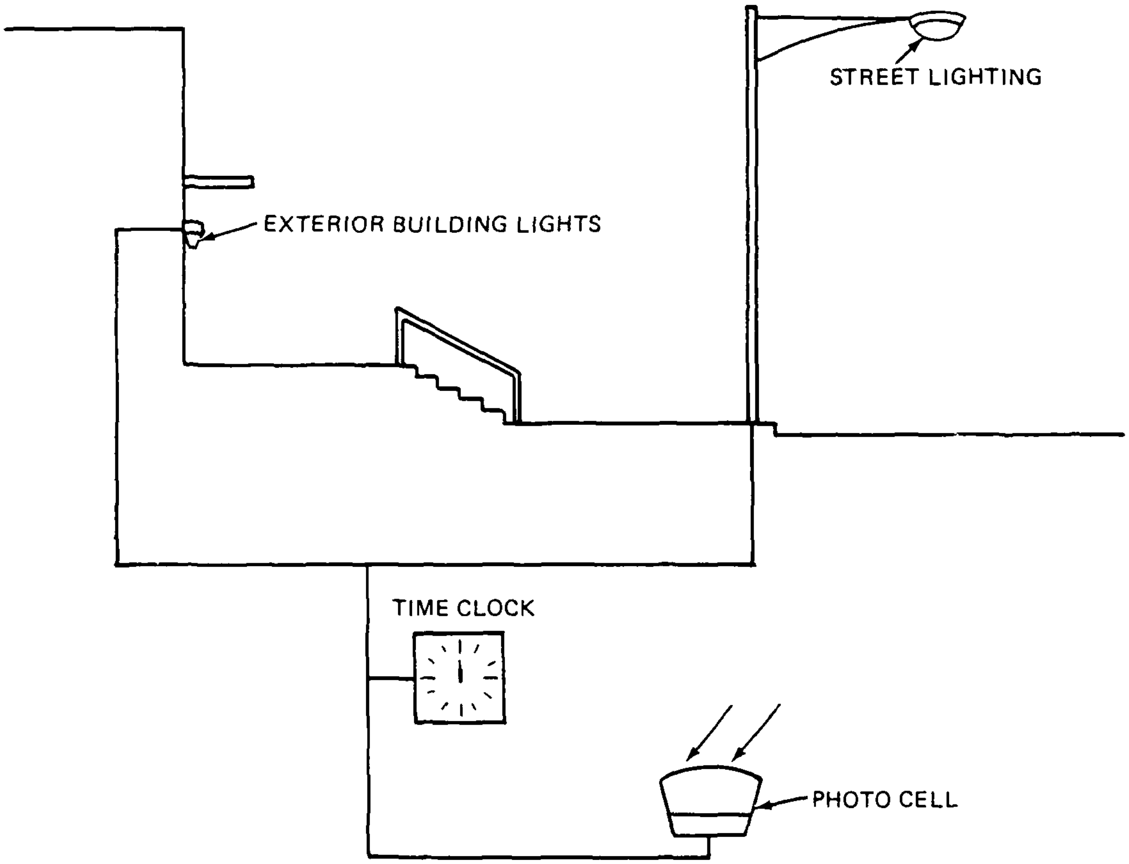


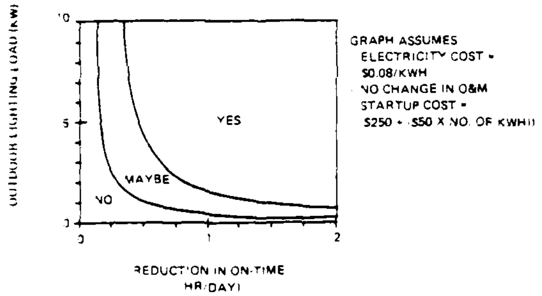
Figure L-6. Control Exterior Lighting

L 6. CONTROL EXTERIOR LIGHTING

DESCRIPTION: Exterior lighting is often responsible for wasted electrical energy. This can result from timeclock (only) operation of lights, where the on/off times are not continuously adjusted for seasonal changes in the length of day. It can also result from maintenance of high levels of illumination throughout the night, when such levels may be needed only for a specific area (such as to accommodate shift work).

To preclude exterior illumination during periods when natural light level is adequate, photocell control (even when timeclocks are also used) must be employed. To take advantage of situations where the same level of exterior illumination is not required throughout the night, timeclock and/or manual control should be employed - but always in conjunction with photocell control.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Required night illumination can be provided automatically while energy is conserved through positive daylight shut off.

SURVEY DATA NEEDS:

- Hours exterior lights are currently used
- Hours exterior lights are required
- Number of exterior fixtures
- Fixture wattage

PROCEDURE:

1. Determine number of hours exterior lights are required/year.
2. Determine number of hours exterior lights are currently used/year.
3. Electrical Savings (kwh/yr) =

$$\text{Number of Fixtures} \times \frac{\text{watts}}{\text{Fixture}} \times \frac{\text{kw}}{1{,}000\ \text{wh}} \times \left[\begin{matrix}\text{Annual} \\ \text{Hours Use} \\ \text{(existing)}\end{matrix} - \begin{matrix}\text{Annual} \\ \text{Hours Use} \\ \text{(required)}\end{matrix}\right]$$

GENERAL INFORMATION:

Sizes Available: N/A
Startup Cost: $440 timeclock and photocell
Replacement Cost: Same as start up cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Startup Cost: $440 timeclock and photocell
- Six fixtures @ 175 watts each
- Existing Operation: 12 hr/day, 365 days/yr
- Required Operation: 9 hr/day, 365 days/yr
- Change in O&M: $5
- Fuel Saved: Electricity
- Energy Cost: $0.08/kwh
- Escalation Rate: 7%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

$$6 \times 175\ \text{w} \times \frac{\text{kw}}{1{,}000\ \text{w}} \times \left[12\ \frac{\text{hr}}{\text{day}} - 9\ \frac{\text{hr}}{\text{day}}\right]$$

$$\times\ 365\ \frac{\text{days}}{\text{yr}} = 1{,}150\ \text{kwh/yr}$$

NES (MBtu/yr) =

$$0 + (1{,}150\ \text{kwh/yr} \times 11{,}600\ \text{Btu/kwh}) \times (\text{MBtu}/10^6\ \text{Btu})$$

= 13.34 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

$$1{,}150\ \frac{\text{kwh}}{\text{yr}} \times \frac{\$0.08}{\text{kwh}}$$

= $92/yr

SIR =

$$\frac{\$92\ (18.049) + (-\$5)\ (9.524)}{\$440\ (1.251)}$$

= 2.9

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EQUIPMENT

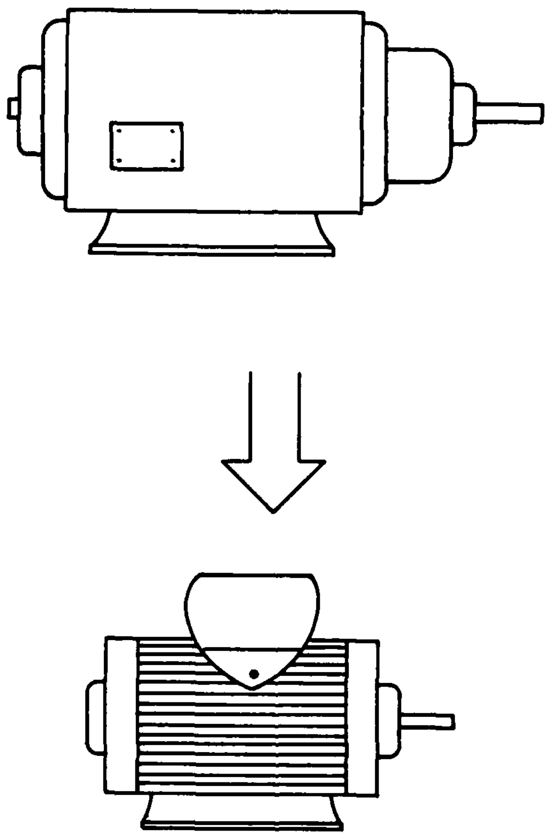
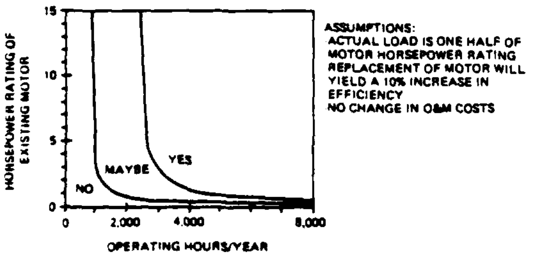


Figure E-1. Replace Oversized Motors

E 1. REPLACE OVERSIZED MOTORS

DESCRIPTION: Electrical motors operate at peak efficiency only at (or near) their rated horsepower. Efficiency decreases as load decreases. Thus, there are needless inefficiencies (i.e., wasted energy) whenever there is not a reasonably close match between load requirement and motor size. Because original load estimates for a building's mechanical equipment are usually conservative, most motors for these systems (e.g., HVAC air handlers) are oversize, motor-load mismatches resulting in inefficiency. This inefficiency may be great enough that immediate replacement (with properly sized, high-efficiency motors) is economically justifiable. Even if this is not the case, downsizing (to match load) should always be considered whenever a motor must be repaired/replaced due to motor failure.

FEASIBILITY REQUIREMENT:



Replacement economic feasibility depends upon the extent to which the existing motor is oversized, characteristics of the motor itself (i.e., efficiency at the load for which presently employed), the cost of a properly sized replacement motor, the replacement motor's efficiency, the cost of electricity, and the operating hours per year. As a rule of thumb, if a continuously operating motor's load is less than 60 percent of its rated horsepower, it is a good candidate for replacement.

BENEFITS/DETRIMENTS: Properly sized motors will save electricity since motors operate most efficiently at their rated horsepower. Possibly offsetting energy savings is increased maintenance (motor repair and/or replacement) resulting from little or no margin between motor load and motor rating (which requires the replacement motor to "work harder" than the oversized one it replaces).

SURVEY DATA NEEDS:

- Records of motor-driven equipment
- Motor nameplate horsepower (hp) (i.e., rated horsepower)
- Number of hours of operation per year for each motor
- Power drawn (as measured with a watt meter), or line voltage, current, and power factor. (If watt meters or power factor meters are not available, power factor will have to be estimated, although this is not nearly as accurate.)

PROCEDURE: To use this procedure, either power must be directly measured (preferred), or voltage and current must be measured.

1. Determine power requirement for existing load (W_{ML}) (including motor losses). If direct reading watt meter is not available, calculate power requirement as follows:

   a. For single-phase motor:

   W_{ML} (in watts) = Line Voltage x Line Current x Power Factor*

   b. For a three-phase motor:

   W_{ML} (in watts) = Line Voltage x Line Current x 1.732 x Power Factor*

   where:

   Line Current = Current in any one of the three legs

   *If power factor must be estimated, use 0.8.

2. Determine ratio of load requirement to existing motor rating as follows:

   Ratio = $\left[W_{ML}/(746 \times 0.75)\right]$/Rated hp

   where:

   W_{ML} = metered load in watts (measured in step 1)

   $W_{ML}/(746 \times 0.75)$ = load requirement in hp

   (This assumes existing motor is operating at 75% efficiency.) If ratio is in the region of 0.6 or less, then motor is sufficiently overrated as to justify replacement.

3. Determine power requirement difference:

   $\Delta P = (1/EFF_E) - (1/EFF_R) \times W_{ML}$

   where:

   EFF_E = Efficiency at which Existing Motor is Operating
   EFF_R = Efficiency of Properly Sized Replacement Motor

   If EFF_E and EFF_R are not readily available (from manufacturer's data, etc.), use as a conservative estimate:

   $\Delta P = 10\% \ W_{ML}$

4. Electrical Savings (kwh/yr) =

   ΔP x (Operating hr/yr) x (1 kw/1,000 watts)

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost (Typically, including labor):

1/2 hp - $190	10 hp - $650
1 hp - $235	15 hp - $750
5 hp - $410	20 hp - $1,000

Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
- Startup Cost: $235
- Measured Power (W_{ML}) to Motor: 535 watts
- Motor is operated continuously.
- Motor manufacturer's performance curves not available.
- Motor Nameplate Data: 1 hp; 120V; 8.2A full load; single phase; PF: 0.95
- Change in O&M: $15 per year
- Fuel Saved: Electricity
- Energy Cost: $0.08/kwh
- Escalation Rate: 7%
- Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Power input measured with watt meter: 535 watts (W_{ML})

Ratio = (535/746) x (0.75)/1 = 0.54

Since this ratio is $\underline{\Delta}$0.6, motor should be replaced.

P = 10% x 535 = 53.5 watts

ELECTRICAL SAVINGS (kwh/yr) =

53.5 watts x 8,760 hr/yr x 1 kw/1,000 watts

= 469 kwh/yr

NES (MBtu/yr) =

0 + 469 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu

= 5.44 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

469 kwh/yr x $0.08/kwh

= $37.52/yr

$$SIR = \frac{\$37.52\ (18.049) + (-\$15)\ (9.524)}{\$235\ (1.251)}$$

$$= 1.8$$

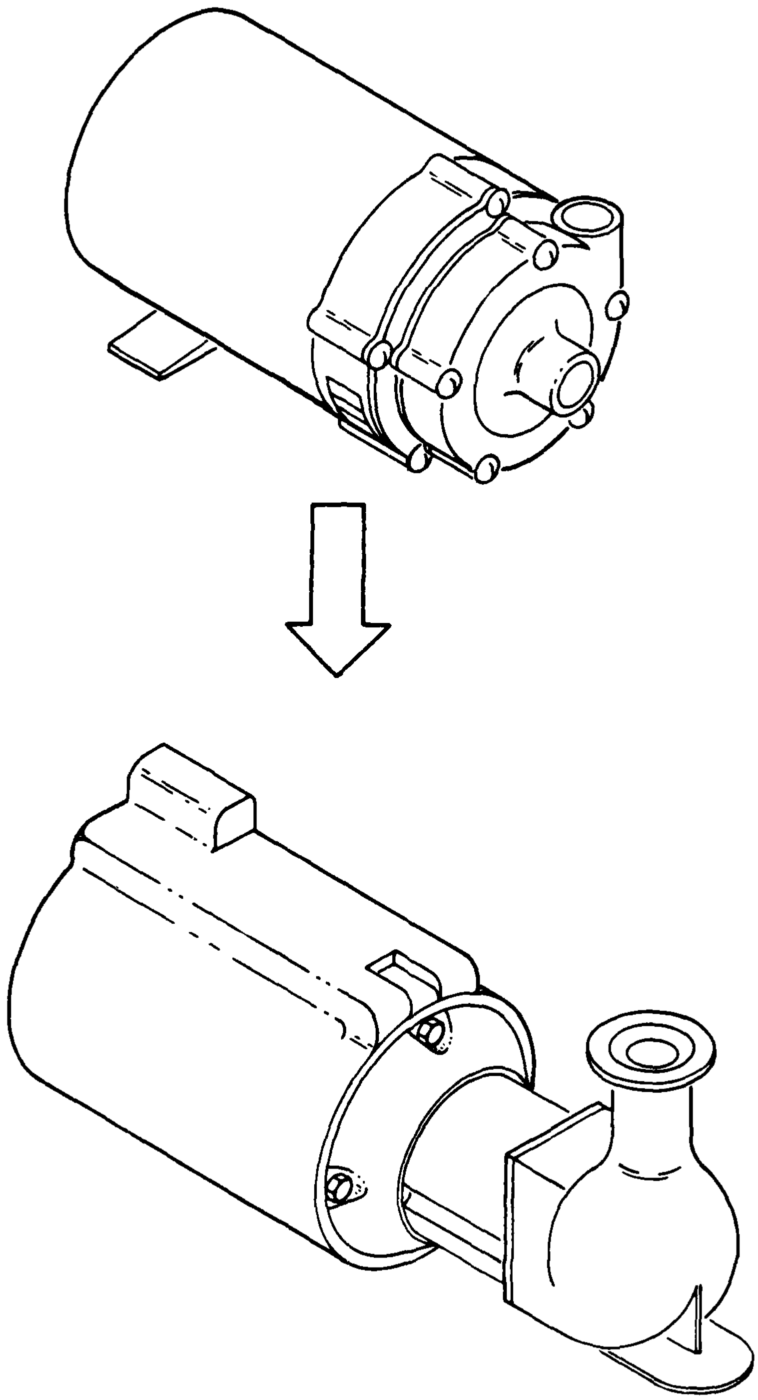


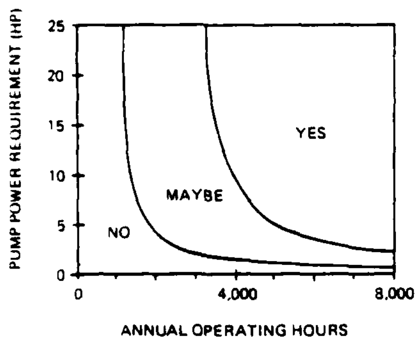
Figure E-2. Replace Inefficient Pumps, Motors

E 2. REPLACE INEFFICIENT PUMPS, MOTORS WITH ENERGY EFFICIENT TYPES

DESCRIPTION: Many motors and pumps that have been in service for several years are inefficient when compared with types readily available today. New pump designs, better machining, and new materials for bearings and seals have resulted in more efficient pumps. In addition, modified motor winding schemes (using more copper to reduce I^2R losses) have resulted in more efficient electrical motors. Thus both pump and motor are contributing to the efficiency improvement. Today's higher energy costs have created the demand for these more efficient systems. Although high-efficiency systems have a higher initial cost, in many instances the resultant savings produce a very favorable savings to investment ratio.

By comparing your calculated efficiencies with those determined from manufacturer's data, the potential for savings through replacement can be determined.

FEASIBILITY REQUIREMENT:



The graph assumes a 10 percent efficiency improvement and an electricity cost of \$0.08/kwh. If more accurate information is not readily available, use pump motor nameplate data for horsepower.

BENEFITS/DETRIMENTS: Replacement of inefficient pumps and motors will save energy with no detriments. Increased reliability may also be experienced as a consequence of the higher precision machinery, higher quality material, and other techniques used to achieve the increases in efficiency.

SURVEY DATA NEEDS:

For each motor/pump:

- Usage information (continuous or intermittent duty, variable or constant load, etc.)
- Measured electrical power drain when operating at normal load* (W_{ML}) If not available, use name plate data (watts)
- Motor nameplate (watt)
- Other nameplate data
- Pump flow rate and pressure head
- Pump performance curves (if available)

*Use watt meter (or measured line voltage, current, and power factor. (Avoid using an estimate of power factor if at all possible.)

PROCEDURE:

1. Determine:

   a. Present motor input power requirement with normal load (W_{ML}).

   b. Required pump pressure head and flow rate.

   c. From manufacturer's data, find most efficient pump and motor that will meet pressure head and flow rate requirements.

2. Electrical Savings (kwh/yr) =

   (W_{ML} - P_N) x Oper hr/yr x 1 kw/1,000 w

   where:

   W_{ML} is measured existing power input in kw
   P_N is input power requirement of replacement pump and motor in watts (assumes 75% efficiency)

GENERAL INFORMATION:

Sizes Available: Various
Startup Cost: Can vary widely. May use \$500 plus \$125 per horsepower for initial estimate if no better cost data is readily available
Replacement Cost: Same as startup cost
Equipment Life: 15 years
Skill Level of Personnel Required: Electrician, plumber
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Energy Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Startup Cost: \$3,000
Pump Requirements: 250 gpm; 150 ft head; 20 hp electric motor drive
Measured Input Power (existing system) (W_{ML}): 17.35 kw (corrected for power factor)
High Efficiency Replacement Pump Input Power Requirement: 15.58 kw (from manufacturer's catalog)
Operating Time: 2,600 hr/yr
Change in O&M: None
Fuel Saved: Electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

(17.35 kw - 15.58 kw) x 2,600 hr/yr

= 4,602 kwh/yr

NES (MBtu/yr) =

4,602 kwh/yr x 11,600 Btu/kwh x MBtu/10^6 Btu

= 53.38 MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

4,602 kwh/yr x $0.08/kwh

= $368.16/yr

$$SIR = \frac{\$368.16\ (18.049)}{\$3{,}000\ (1.251)}$$

= 1.8

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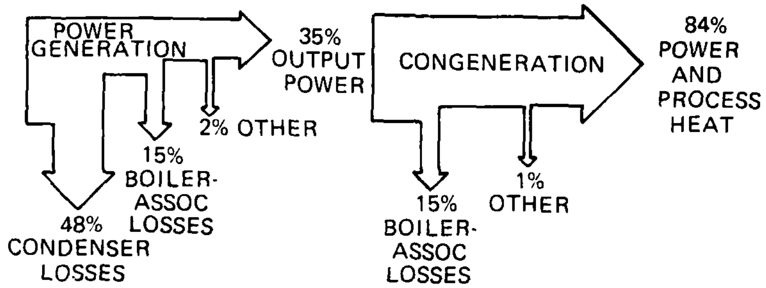
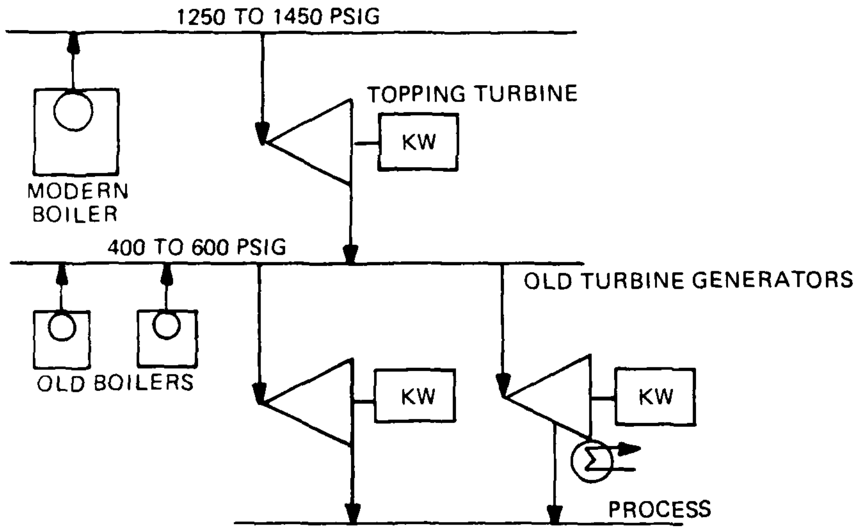
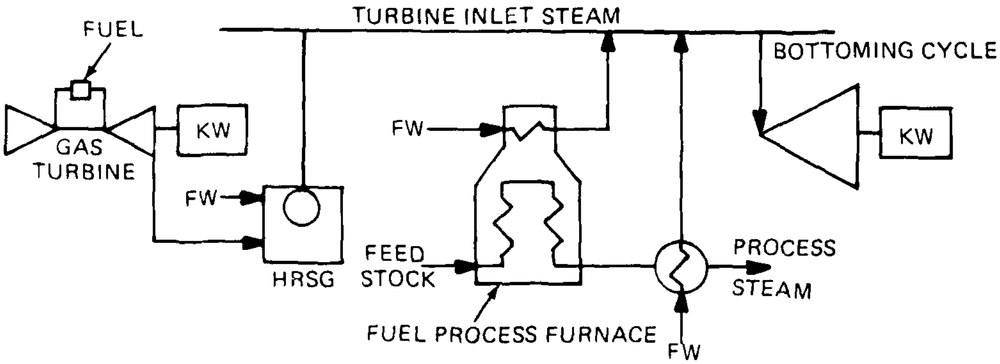
COGENERATION



FUEL UTILIZATION EFFECTIVENESS OF STEAM POWER PLANTS



SCHEMATIC DIAGRAM OF A TOPPING STEAM TURBINE-GENERATOR



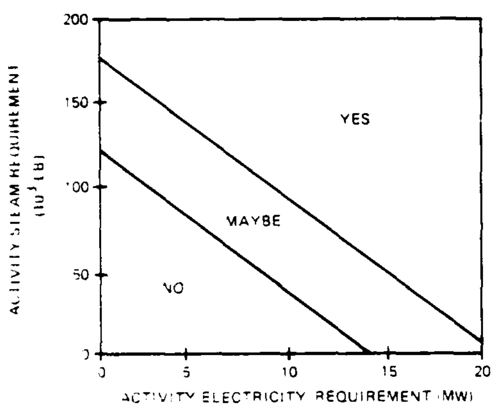
EXAMPLES OF HEAT SOURCES FOR STEAM TURBINE BOTTOMING CYCLES

Figure C-1. Oil-Fired Cogeneration Systems

C 1. OIL-FIRED COGENERATION SYSTEMS

DESCRIPTION: In cogeneration systems, electrical or mechanical energy and useful thermal energy are produced simultaneously. These improved energy systems utilize more of the heat energy produced when conventional fuels are burned than is possible with existing single systems. As shown in the illustration on the facing page, cogeneration systems can yield net fuel savings of up to 50 percent compared to separate single systems. There are two types of cogeneration systems, topping and bottoming. In a topping system, electricity or mechanical power is produced first and the exhaust from the turbine (see illustration) is used for industrial processes, space heating, or other uses. The bottoming system reverses the order, i.e., power generation comes last.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: In conventional steam power generation systems, about two-thirds of the heat transferred from the fuel to the steam is released, unused, to the environment. Much of this wasted heat can be saved by cogeneration (see illustration, facing page). For a cogenerating system to be economically feasible, a somewhat stable demand for electricity and steam is needed. For example, if both electricity and heat are produced for a residential community, the hourly demand for both power and heat can vary by the hour. Cogeneration systems should be tied in with a utility electrical grid so that excess power during low demand can be sold to the utility and, in the case of peak demand, the utility can augment the cogenerator.

Cogeneration systems are more complicated than single systems, resulting in higher capital investment. Cogeneration installations will not be made when investment, maintenance, and fuel costs are not balanced by fuel savings. The sharp increase in energy costs recently should make cogeneration more attractive.

SURVEY DATA NEEDS:

- Identify gas-combustion turbine exhaust sources
- Application of topping system
- Application of bottoming system
- Startup cost and O&M for electric plant
- Startup cost and O&M for steam plant
- Startup cost and O&M for cogenerating plant
- Oil cost, electric only
- Oil cost, steam only
- Oil cost, cogeneration only
- Electric cost

PROCEDURE:

1. Determine present fuel and electric costs. Fuel savings are the essential advantage of cogeneration.

2. Estimate the amount of savings attributable to the proposed cogeneration facility. For estimating purposes an 18% savings in fuel and electric costs can be expected with installation of a cogeneration system.

3. Determine cogeneration operation and maintenance costs. For estimating purposes an 18% savings in O&M costs of combined electric and steam plants over individual plants can be expected with installation.

4. Use data from ES options P 1 and S 1 for incumbent power and steam plant costs.

5. Evaluate economic feasibility.

GENERAL INFORMATION:

Sizes Available: 10 Mw - 30 Mw
Startup Cost: $1,300/kw (estimate)
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Engineering firm specializing in cogeneration systems
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

(Fuel Cost) (DERF) + (Electric Cost) (DERF) -

(Cogeneration Cost) (DERF) + (($O\&M_{Steam}$ + $O\&M_{Electric}$)-

$O\&M_{cogen}$) x (PYDF)/C(PIF)

SAMPLE CALCULATION:

Assumptions:
Size: 10 Mw (electricity)
100 MBtu (steam)
Annual Fuel Cost for Incumbent Steam Plant: $4.911M
Annual Fuel Cost for Incumbent Electric Plant: $5.078M
Annual O&M Cost for Incumbent Steam Plant: $0.232M
Annual O&M Cost for Incumbent Electric Plant: $0.513M
Startup Cost: $13M
Fuel Saved: Steam, electricity
Energy Cost Rate: $10/MBtu (steam), $0.08/kwh (electricity)
Escalation Rate: 8%, 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Estimated Steam Savings =

0.18 (Annual Fuel Cost for Incumbent)

= 0.18 ($\$4.911 \times 10^6$/yr)

= $\$8.84 \times 10^5$/yr

Estimated Electric Savings =

0.18 (Annual Fuel Cost for Incumbent)

$= 0.18 (\$5.078 \times 10^6/yr)$

$= \$9.14 \times 10^5/yr$

Estimated O&M Savings for Cogeneration =

0.18 (Annual O&M Cost for Incumbent Steam) +

0.18 (Annual O&M Cost for Incumbent Electric)

$= 0.18 (\$0.232 \times 10^6) + 0.18 (\$0.513 \times 10^6)$

$= \$4.18 \times 10^4 + \$9.2 \times 10^4$

$= \$1.38 \times 10^5$

FUEL SAVINGS (MBtu/yr) =

$$\frac{\text{Estimated Savings (\$/yr)}}{\text{Cost of Steam (\$/MBtu)}}$$

$$= \frac{\$8.84 \times 10^5/yr}{\$10/MBtu}$$

= 8,840 MBtu/yr

ELECTRICAL SAVINGS (kwh/yr) =

$$\frac{\text{Estimated Savings}}{\text{Cost of Electricity}}$$

$$= \frac{\$9.14 \times 10^5/yr}{\$0.08/kwh}$$

$= 1.14 \times 10^7$ kwh/yr

NES (MBtu/yr) =

8,840 MBtu + (1.14×10^7 kwh/yr x 11,600 Btu/kwh)

= 14,108 MBtu

FUEL COST SAVINGS ($/yr) =

Estimated Steam Savings = $0.884M/yr

ELECTRICITY COST SAVINGS ($/yr) =

Estimated Electric Savings = $0.914M/yr

SIR =

$$\frac{\$0.884M\ (20.05) + \$0.914M\ (18.049) + \$0.138M\ (PYDF)}{\$13M\ (1)}$$

= 2.7

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STEAM

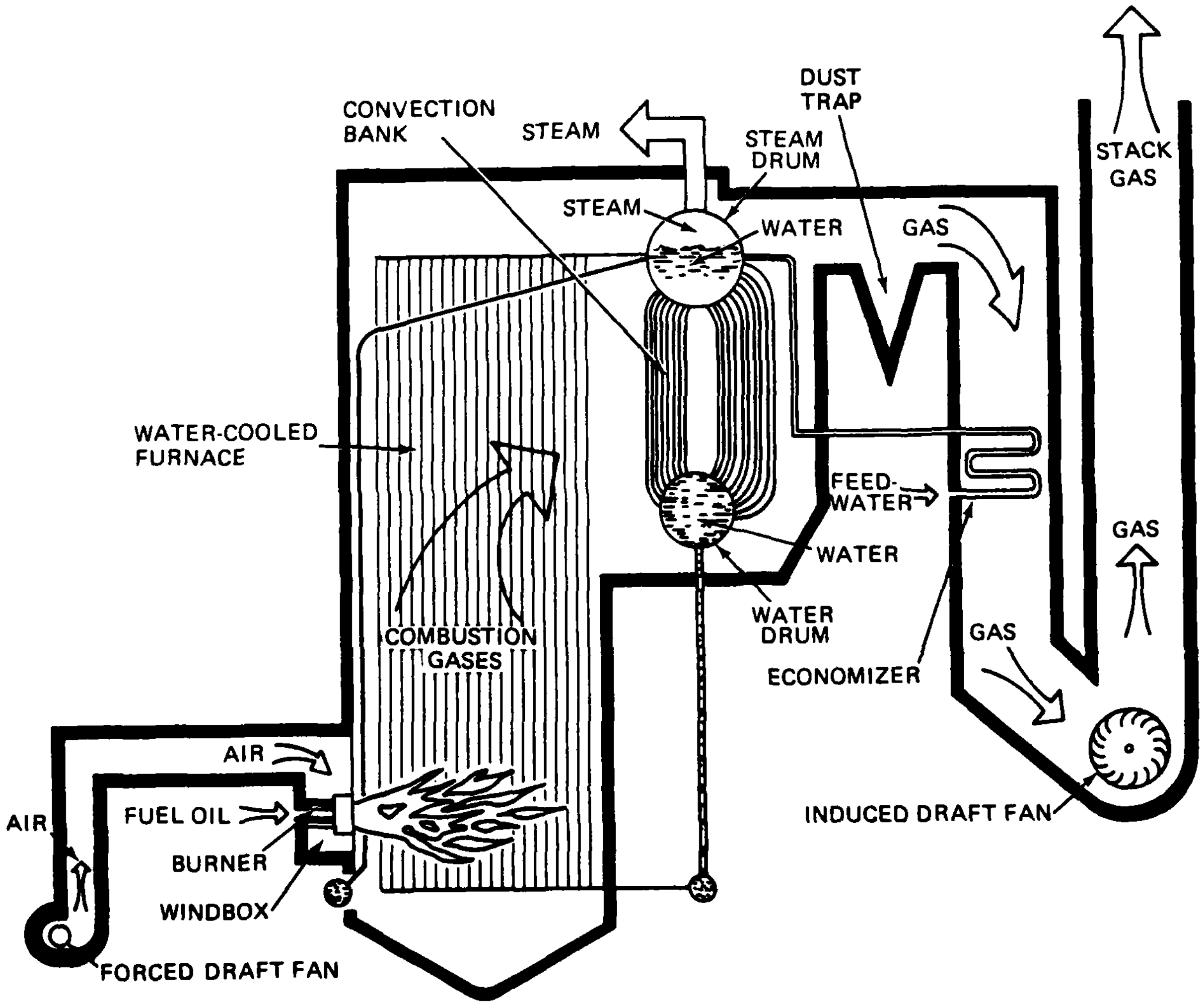


Figure S-1. Oil-Fired Central Heating Plant

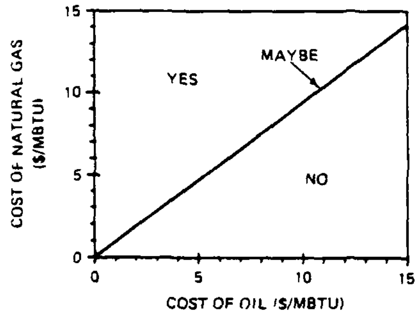
S 1. OIL-FIRED CENTRAL HEATING PLANT

DESCRIPTION: The Navy shore establishment operates numerous central heating plants which utilize petroleum as the primary fuel. The illustration on the facing page shows a typical configuration for a two-drum Stirling boiler at a central heating plant. No. 2, No. 5, or No. 6 fuel oil can be used to fire the boiler. No. 6 fuel oil must be heated before it can be used. The fuel is mixed with air in the burners, atomized into a fine mist, and burned in a water-cooled furnace. Hot combustion gases pass through the convection bank of water tubes. An induced draft fan pulls the gases through an economizer, in which the feedwater is heated. The gases then exit out the stack. Steam is generated by radiant heat from the furnace and convective heat in the convection bank. The steam is separated in the steam drum and exits the plant at a medium temperature and pressure (e.g., 390°F and 200 psig) to be used for heating and industrial purposes.

Definitive designs for oil-fired central heating plants are provided in NAVFAC P-272, part 2.

In designing a central heating plant to meet a new energy demand, the procedures provided in NAVFAC DM-3, chapter 8 should be followed. The procedure provided in this option covers replacement of an existing central heating plant with a new plant based on cost savings.

FEASIBILITY REQUIREMENT:



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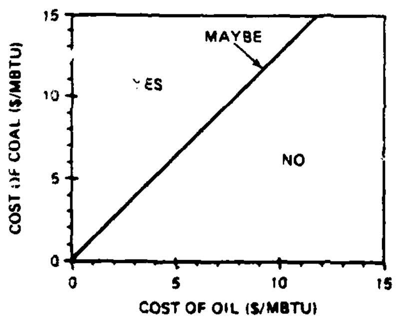


BENEFITS/DETRIMENTS: This boiler design has been perfected over a period of 100 years and is, therefore, reliable and predictable. The primary detriments to this boiler are the high cost of fuel oil and the occasional disruptions in supply.

SURVEY DATA NEEDS:

- Annual energy output of existing plant
- Annual fuel usage of existing plant
- Efficiency of existing plant
- Maximum recorded steam demand
- Minimum recorded steam demand
- Essential load
- Ultimate load

PROCEDURE:

1. Calculate annual energy output of existing plant, based on steam logs or fuel usage. If fuel records are used:

   Annual energy Output (MBtu/yr) = Annual Fuel Usage (MBtu/yr) x Existing Plant Efficiency (0.75 to 0.80)

2. Evaluate fluctuations in steam load based on logs or fuel usage over two or more years. Determine:

   - Maximum recorded demand (lb/hr)
   - Minimum recorded demand (lb/hr)
   - Essential load (lb/hr)
   - Ultimate load (lb/hr)

   The essential load is the minimum steam load to meet all necessary heating/process requirements at the activity after cutbacks have been instituted. Determination of this load may be based on steam logs or specific load calculations (see DM-3). The ultimate load is the estimated demand for steam in future years. Either the new plant should be sized for this load or provisions should be made for future expansion.

3. Rated Capacity of New Plant (lb/hr) = Maximum Observed Steam Demand (lb/hr) or Ultimate Load (lb/hr) x Safety Factor (1.0 to 1.5)

4. Provide more than one boiler in the plant. For a plant with three boilers of equal size, both of these conditions must be met for each boiler:

   Boiler Rated Capacity (lb/hr) = Plant Rated Capacity (lb/hr) x $\frac{1}{3}$

   Boiler Rated Capacity (lb/hr) $\geq$ Essential Steam Load (lb/hr) x $\frac{1}{2}$

5. Minimum Boiler Operating Capacity (lb/hr) $\leq$ Minimum Recorded Demand (lb/hr) x Safety Factor (1.0 to 0.7)

6. Annual Energy Input to New System (MBtu/yr) = $\dfrac{\text{Annual Energy Output (MBtu/yr) from Step 1}}{\text{New System Efficiency (0.80 to 0.85)}}$

GENERAL INFORMATION:

Boiler Sizes Available: 200 to 150,000 lb/hr
Startup Cost: $10 to $15 per lb/hr steam
Replacement Cost: Same as startup cost
Equipment Life: 25 years

Skill Level of Personnel Required: For central heating plant, skilled boiler plant operator and maintenance personnel.

Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/hr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{E_{gas}(DERF) - E_{oil}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:

Existing system is a natural gas heating plant.
Annual Fuel Usage of Existing Plant: 9.83×10^{11} Btu
Efficiency of Existing Plant: 75%
Maximum Recorded Steam Demand: 125,000 lb/hr
Minimum Recorded Demand: 20,000 lb/hr
Essential Steam Load: 85,000 lb/hr
Ultimate Steam Load: 135,000 lb/hr
Startup Cost: $2.20M
Change in O&M: $0.005M/yr increase
Fuel Saved: Natural gas
Energy Cost: $4.14/MBtu (oil), $6.00/MBtu (gas)
Escalation Rate: 8% oil, 8% gas
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Annual Energy Output} = \text{Annual Fuel Usage} \times \text{Existing System Efficiency}$$

$$= (9.83 \times 10^{11}\ \text{Btu/yr}) \times (0.75)$$

$$= 7.37 \times 10^{11}\ \text{Btu/yr}$$

$$\text{Rated Capacity of New Plant} = \text{Ultimate Load} \times \text{Safety Factor}$$

$$= (135{,}000\ \text{lb/hr}) \times (1.1)$$

$$= 148{,}500\ \text{lb/hr*}$$

*Round off to 150,000 lb/hr

$$\text{Boiler Rated Capacity} = \text{Plant Rated Capacity} \times \frac{1}{3}$$

$$= (150{,}000\ \text{lb/hr}) \times \frac{1}{3}$$

$$= 50{,}000\ \text{lb/hr}$$

$$\text{Boiler Rated Capacity} \geq \text{Essential Steam Load} \times \frac{1}{2}$$

$$50{,}000\ \text{lb/hr} \geq (85{,}000\ \text{lb/hr}) \times \frac{1}{2}$$

$$\geq 42{,}500\ \text{lb/hr}$$

$$\text{Minimum Boiler Operating Capacity} \leq \text{Minimum Recorded Demand} \times \text{Safety Factor}$$

$$\leq (20{,}000\ \text{lb/hr}) \times (0.9)$$

$$\leq 18{,}000\ \text{lb/hr}$$

A burner turndown ratio of 3:1 will accommodate the minimum operating capacity.

$$\text{Annual Energy Input to New System} = \frac{\text{Annual Energy Output}}{\text{New System Efficiency}}$$

$$= \frac{7.37 \times 10^{11}\ \text{Btu/yr}}{0.80}$$

$$= 9.21 \times 10^{11}\ \text{Btu/yr}$$

FUEL SAVINGS (MBtu/yr) =

$$9.83 \times 10^5\ \text{MBtu/yr} - 9.21 \times 10^5\ \text{MBtu/yr}$$

$$= 6.20 \times 10^4\ \text{MBtu/yr}$$

NES (MBtu/yr) =

$$6.20 \times 10^4\ \text{MBtu/yr}$$

$$= 6.20 \times 10^4\ \text{MBtu/yr}$$

FUEL COST SAVINGS ($/yr) =

$$((9.83 \times 10^5\ \text{MBtu/yr} \times \$6.00/\text{MBtu}) -$$

$$(9.21 \times 10^5\ \text{MBtu/yr} \times \$4.14/\text{MBtu}))$$

$$= \$2.09\text{M/yr}$$

SIR =

$$\frac{\$5.90\text{M}\ (20.05) - \$3.81\text{M}\ (20.05) + (-\$0.005\text{M})(9.524)}{\$2.20\text{M}\ (1)}$$

$$= 19.0$$

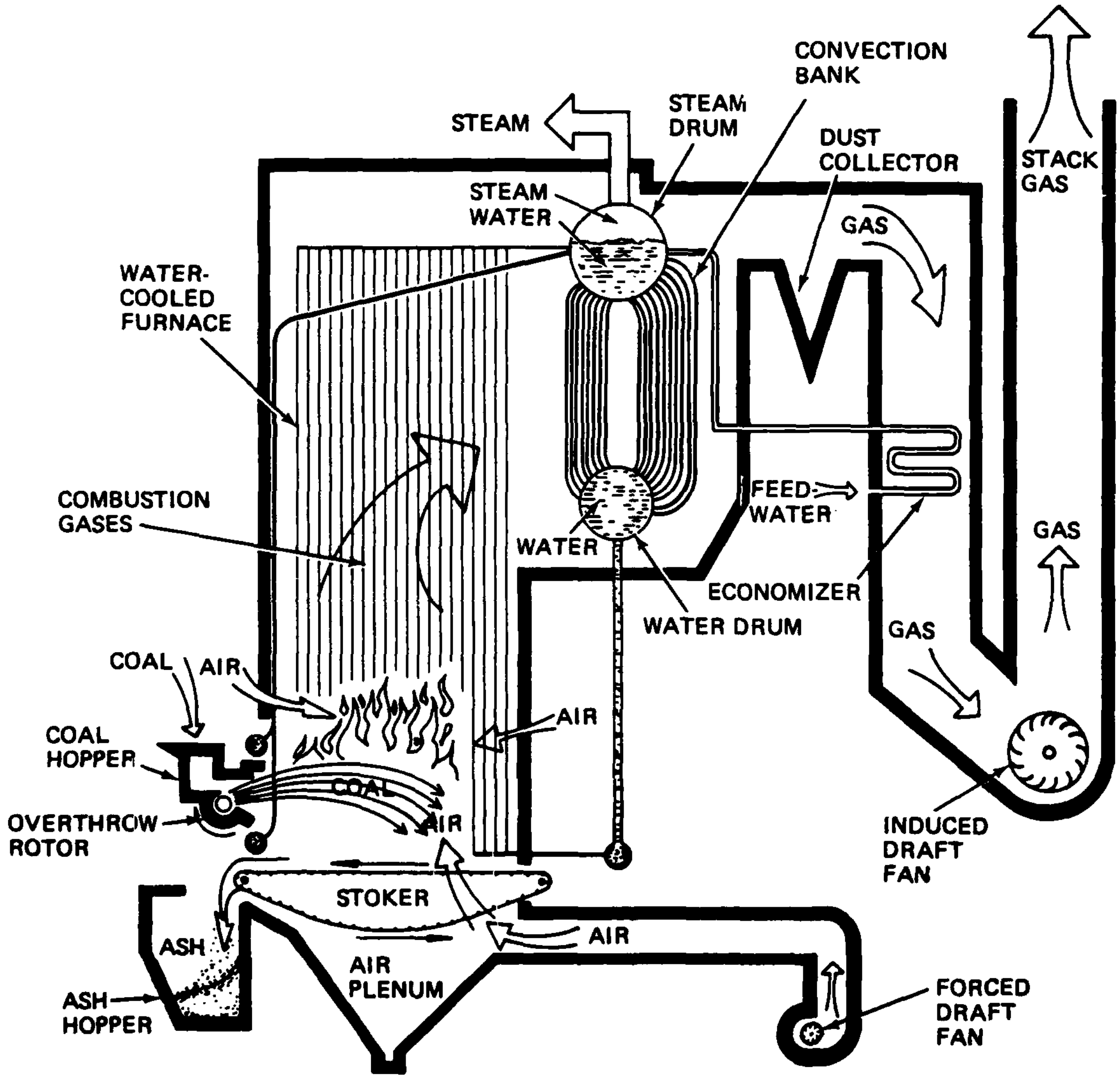


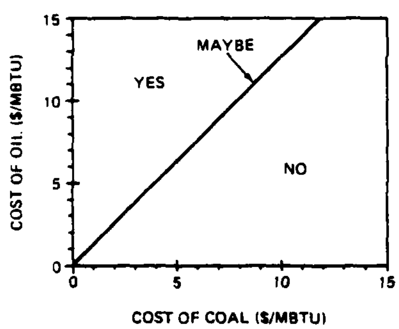
Figure S-2. Coal-Fired Central Heating Plant

<u>DESCRIPTION</u>: The Navy shore establishment operates many central heating plants which utilize coal as the primary fuel. The illustration on the facing page shows a typical configuration for a two-drum Stirling boiler at a central heating plant. The boiler employs a spreader stoker which is capable of burning a wide range of coals, from high-ranked Eastern bituminous to lignite or brown coal. The spreader stoker projects fuel into the furnace over the fire with a uniform spreading action, permitting suspension burning of the fine fuel particles. Heavy pieces fall to the grate for combustion in a thin fast-burning bed. Both undergrate and overfire air is provided to the water-cooled furnace. Hot combustion gases pass through the convection bank of water tubes. An induced draft fan pulls the gases through an economizer in which the feedwater is heated. The gases then exit out the stack. Particulates are removed from stack gases through the use of air pollution control devices such as electrostatic precipitators. Steam is generated by radiant heat from the furnace and convective heat in the convection bank. The steam is separated in the steam drum and exits the plant at medium temperature and pressure (e.g., 390°F and 200 psig) to be used for heating and industrial purposes.

Definitive designs for coal-fired central heating plants are provided in NAVFAC P-272, part 2.

In designing a central heating plant to meet a new energy demand, the procedures provided in NAVFAC DM-3, chapter 8, should be followed. The procedure provided in this option covers replacement of an existing central heating plant with a new plant based on cost savings.

<u>FEASIBILITY REQUIREMENT</u>:



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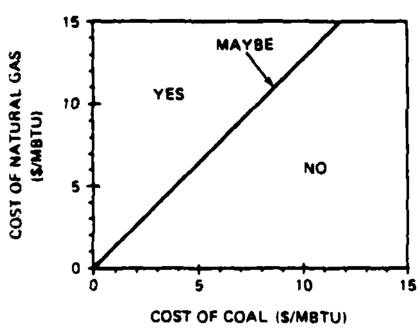


<u>BENEFITS/DETRIMENTS</u>: This boiler design has been perfected over a period of 100 years and is, therefore, reliable and predictable. Coal is a relatively low cost conventional fuel with large reserves throughout the United States. Detriments associated with the fuel and the boiler plant include: (1) the "dirty" nature of coal burning which necessitates the use of capital- and power-intensive air pollution control equipment, (2) much higher startup and operation and maintenance costs than other conventional fuels due to greater fuel handling and preparation requirements, and (3) significant ash disposal requirements.

<u>SURVEY DATA NEEDS</u>:

- Annual energy output of existing plant
- Annual fuel usage of existing plant
- Efficiency of existing plant
- Maximum recorded steam demand
- Minimum recorded steam demand
- Essential load
- Ultimate load

<u>PROCEDURE</u>:

1. Calculate annual energy output of existing plant based on steam logs or fuel usage. If fuel records are used:

   Annual Energy Output (MBtu/yr) = Annual Fuel Usage (MBtu/yr) x Existing Plant Efficiency (0.75 to 0.80)

2. Evaluate fluctuations in steam load based on logs or fuel usage over two or more years. Determine:

   - Maximum recorded demand (lb/hr)
   - Minimum recorded demand (lb/hr)
   - Essential load (lb/hr)
   - Ultimate load (lb/hr)

   The essential load is the minimum steam load to meet all necessary heating/process requirements at the activity after cutbacks have been instituted. Determination of this load may be based on steam logs or specific load calculations (see DM-3). The ultimate load is the estimated demand for steam in future years. Either the new plant should be sized for this load or provisions should be made for future expansion.

3. Rated Capacity of New Plant (lb/hr) = Maximum Observed Steam Demand (lb/hr) or Ultimate Load (lb/hr) x Safety Factor (1.0 to 1.5)

4. Provide more than one boiler in the plant. For a plant with three boilers of equal size, both of these conditions must be met for each boiler:

   Boiler Rated Capacity (lb/hr) = Plant Rated Capacity (lb/hr) x $\frac{1}{3}$

   Boiler Rated Capacity (lb/hr) $\geq$ Essential Steam Load (lb/hr) x $\frac{1}{2}$

5. Minimum Boiler Operating Capacity (lb/hr) $\geq$ Minimum Recorded Demand (lb/hr) x Safety Factor (1.0 to 0.7)

6. Annual Energy Input to New System (MBtu/yr) = $\frac{\text{Annual Energy Output (MBtu/yr) from Step 1}}{\text{New System Efficiency (0.80 to 0.85)}}$

S 2. COAL-FIRED CENTRAL HEATING PLANT - CONTINUED

GENERAL INFORMATION:

Boiler Sizes Available: 1,000 to 150,000 lb/hr
Startup Cost: $30 to 40 per lb/hr steam
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: For central heating plant, skilled boiler plant operators and maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{E_{oil}(DERF) - E_{coal}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Existing system is an oil-fired heating plant.
Annual Fuel Usage of Existing Plant: 9.83×10^{11} Btu
Efficiency of Existing Plant: 75%
Maximum Recorded Steam Demand: 125,000 lb/hr
Minimum Recorded Demand: 20,000 lb/hr
Essential Steam Load: 85,000 lb/hr
Ultimate Steam Load: 135,000 lb/hr
Startup Cost: $5.20M
$O\&M_{exist}$ = $0.375M/yr
$O\&M_{new}$ = $0.640M/yr
Change in O&M: $0.265M/yr
Fuel Saved: No. 6 fuel oil
Energy Cost: $4.14/MBtu (oil), $1.902/MBtu (coal)
Escalation Rate: 8% oil, 5% coal
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Annual Energy Output} = \text{Annual Fuel Usage} \times \text{Existing System Efficiency}$$

$$= (9.83 \times 10^{11}\ \text{Btu/yr}) \times (0.75)$$

$$= 7.37 \times 10^{11}\ \text{Btu/yr}$$

$$\text{Rated Capacity of New Plant} = \text{Ultimate Load} \times \text{Safety Factor}$$

$$= (135,000\ \text{lb/hr}) \times 1.1$$

$$= 148,500\ \text{lb/hr*}$$

*Round off to 150,000 lb/hr

$$\text{Boiler Rated Capacity} = \text{Plant Rated Capacity} \times \frac{1}{3}$$

$$= (150,000\ \text{lb/hr}) \times \frac{1}{3}$$

$$\text{Boiler Rated Capacity} \geq \text{Essential Steam Load} \times \frac{1}{2}$$

$$\geq (85,000\ \text{lb/hr}) \times \frac{1}{2}$$

$$50,000\ \text{lb/hr} \geq 42,500\ \text{lb/hr}$$

$$\text{Minimum Boiler Operating Capacity} \leq \text{Minimum Recorded Demand} \times \text{Safety Factor}$$

$$\leq (20,000\ \text{lb/hr}) \times 0.9$$

$$\leq 18,000\ \text{lb/hr}$$

A combustion operating range of 3:1 will accommodate the minimum operating capacity.

$$\text{Annual Energy Input to New System} = \frac{\text{Annual Energy Output}}{\text{New System Efficiency}}$$

$$= \frac{7.37 \times 10^{11}\ \text{Btu/yr}}{0.80}$$

$$= 9.21 \times 10^{11}\ \text{Btu/yr}$$

FUEL SAVINGS (MBtu/yr) =

9.83×10^5 MBtu/yr - 9.21×10^5 MBtu/yr

= 6.20×10^4 MBtu/yr

NES (MBtu/yr) =

6.20×10^4 MBtu/yr

= 6.20×10^4 MBtu/yr

FUEL COST SAVINGS ($/yr) =

9.83×10^5 MBtu/yr x $4.14/MBtu -

9.21×10^5 MBtu/yr x $1.902/MBtu

= $2.32M/yr

SIR =

$$\frac{\$4.07M\ (20.050) - \$1.75\ (1\ .777) + (-\$0.265M)\ (9.524)}{\$5.20M\ (1)}$$

= 10.2

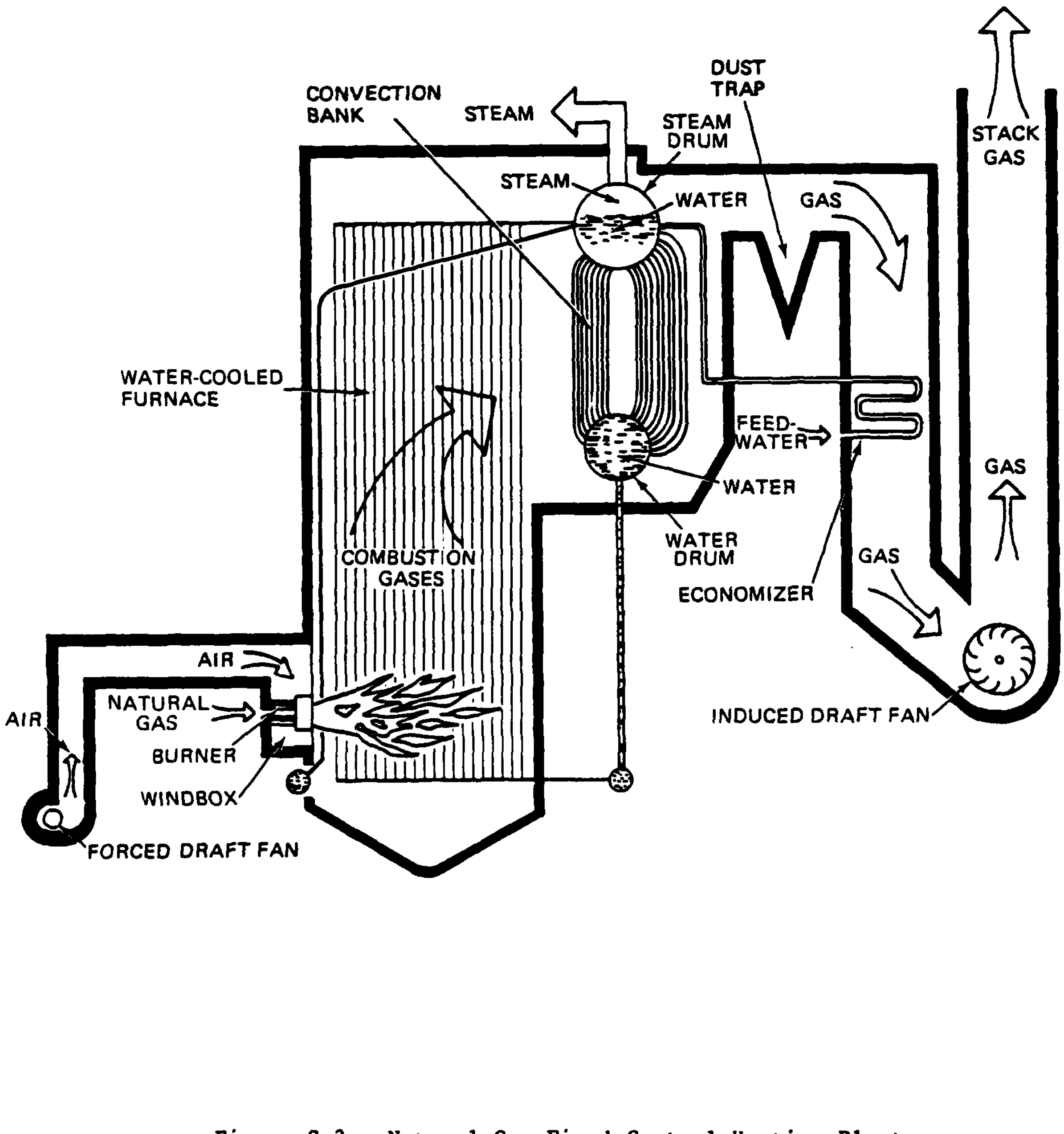


Figure S-3. Natural Gas-Fired Central Heating Plant

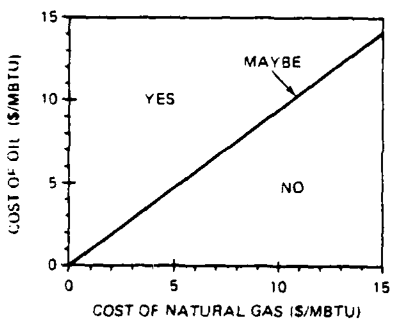
S 3. NATURAL GAS-FIRED CENTRAL HEATING PLANT

DESCRIPTION: Natural gas is an excellent, clean-burning fuel for central heating plants. The illustration on the facing page shows a typical configuration for a two-drum Stirling boiler at a central heating plant. The fuel is mixed with air in the burners and introduced into a water-cooled furnace for combustion. Burners are generally designed to burn fuel oil as well as natural gas. Hot combustion gases pass through the convection bank of water tubes. An induced draft fan pulls the gases through an economizer, in which the feedwater is heated. The gases then exit out of the stack. Steam is generated by radiant heat from the furnace and convective heat in the convection bank. The steam is separated in the steam drum and exits the plant at a relatively low temperature and pressure (e.g., 390°F and 200 psig) to be used for heating and industrial purposes.

Definitive designs for natural gas-fired central heating plants are provided in NAVFAC P-272, part 2.

In designing a central heating plant to meet a new energy demand, the procedures provided in NAVFAC DM-3, chapter 8, should be followed. The procedure provided in this option covers replacement of an existing central heating plant with a new plant based on cost savings.

FEASIBILITY REQUIREMENT:



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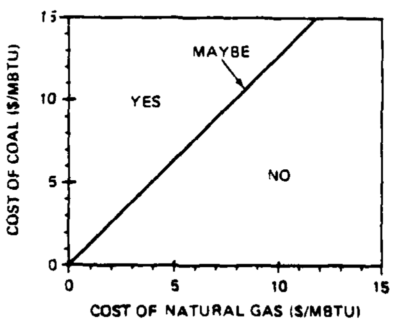


BENEFITS/DETRIMENTS: This boiler design has been perfected over a period of 100 years and is, therefore, reliable and predictable. Natural gas is a clean-burning fuel with few, if any, air pollution control requirements. The primary detriments to this system are the high cost of natural gas and the occasional disruptions in supply. The cost of natural gas promises to escalate rapidly due to the phased deregulation of the fuel.

SURVEY DATA NEEDS:

- Annual energy output of existing plant
- Annual fuel usage of existing plant
- Efficiency of existing plant
- Maximum recorded steam demand
- Minimum recorded steam demand
- Essential load
- Ultimate load

PROCEDURE:

1. Calculate annual energy output of existing plant based on steam logs or fuel usage. If fuel records are used:

   Annual Energy Output (MBtu/yr) = Annual Fuel Usage (MBtu/yr) x Existing Plant Efficiency (0.75 to 0.80)

2. Evaluate fluctuations in steam load based on logs or fuel usage over two or more years. Determine:

   - Maximum recorded demand (lb/hr)
   - Minimum recorded demand (lb/hr)
   - Essential load (lb/hr)
   - Ultimate load (lb/hr)

   The essential load is the minimum steam load to meet all necessary heating/process requirements at the activity after cutbacks have been instituted. Determination of this load may be based on steam logs or specific load calculations (see DM-3). The ultimate load is the estimated demand for steam in future years. Either new plant should be sized for this load or provisions should be made for future expansion.

3. Rated Capacity of New Plant (lb/hr) = Maximum Observed Steam Demand (lb/hr) or Ultimate Load (lb/hr) x Safety Factor (1.0 to 1.5)

4. Provide more than one boiler in the plant. For a plant with three boilers of equal size, both of these conditions must be met for each boiler:

   $$\text{Boiler Rated Capacity (lb/hr)} = \text{Plant Rated Capacity (lb/hr)} \times \frac{1}{3}$$

   $$\text{Boiler Rated Capacity (lb/hr)} \geq \text{Essential Steam Load (lb/hr)} \times \frac{1}{2}$$

5. $$\text{Minimum Boiler Operating Capacity (lb/hr)} \leq \text{Minimum Recorded Demand (lb/hr)} \times \text{Safety Factor (1.0 to 0.7)}$$

6. $$\text{Annual Energy Input to New System (MBtu/yr)} = \frac{\text{Annual Energy Output (MBtu/yr) from Step 1}}{\text{New System Efficiency (0.80 to 0.85)}}$$

GENERAL INFORMATION:

Boiler Sizes Available: 200 to 150,000 lb/hr
Startup Cost: $10 to $15 per lb/hr steam
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: For central heating plant, skilled boiler plant operators and maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{E_{oil}(DERF) - E_{gas}(DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Existing system is an oil fired heating plant.
Annual Fuel Usage of Existing Plant: 9.83×10^{11} Btu
Efficiency of Existing Plant: 75%
Maximum Recorded Steam Demand: 125,000 lb/hr
Minimum Recorded Demand: 20,000 lb/hr
Essential Steam Load: 85,000 lb/hr
Ultimate Steam Load: 135,000 lb/hr
Startup Cost: $2.03M
$O\&M_{exist}$ = $0.375M/yr
$O\&M_{new}$ = $0.370M/yr
Change in O&M: $0.005M/yr
Fuel Saved: No. 6 fuel oil
Energy Cost: $4.14/MBtu (oil), $6.00/MBtu (gas)
Escalation Rate: 8% oil, 8% gas
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Annual Energy Output = Annual Fuel Usage x Existing System Efficiency

$= 9.83 \times 10^{11}$ Btu/yr x 0.75

$= 7.37 \times 10^{11}$ Btu/yr

Rated Capacity of New Plant = Ultimate Load x Safety Factor

= 135,000 lb/hr x 1.1

= 148,500 lb/hr*

*Round off to 150,000 lb/hr

Boiler Rated Capacity = Plant Rated Capacity $\times \frac{1}{3}$

$= 150{,}000$ lb/hr $\times \frac{1}{3}$

= 50,000 lb/hr

Boiler Rated Capacity $\geq$ Essential Steam Load $\times \frac{1}{2}$

$\geq 85{,}000$ lb/hr $\times \frac{1}{2}$

x 50,000 lb/hr $\geq$ 42,000 lb/hr

Minimum Boiler Operating Capacity $\geq$ Minimum Recorded Demand x Safety Factor

$\geq$ 20,000 lb/hr x 0.9

$\geq$ 18,000 lb/hr

A burner turndown ratio of 3:1 will accommodate the minimum operating capacity.

Annual Energy Input to New System = $\frac{\text{Annual Energy Output}}{\text{New System Efficiency}}$

$= \frac{7.37 \times 10^{11}\ \text{Btu/yr}}{0.80}$

Annual Energy Input to New System $= 9.21 \times 10^{11}$ Btu/yr

FUEL SAVINGS (MBtu/yr) =

9.83×10^5 MBtu/yr $- 9.21 \times 10^5$ MBtu/yr

$= 6.20 \times 10^4$ MBtu/yr

NES (MBtu/yr) =

6.20×10^4 MBtu/yr

$= 6.20 \times 10^4$ MBtu/yr

FUEL COST SAVINGS ($/yr) =

9.83×10^5 MBtu/yr x $4.14/MBtu

$- 9.21 \times 10^5$ MBtu/yr x $6.00/MBtu

= - $1.46/yr

SIR =

$$\frac{\$4.07M\ (20.05) - \$5.53M\ (20.05) + \$0.005M\ (9.524)}{\$2.03M\ (1)}$$

= -14.4

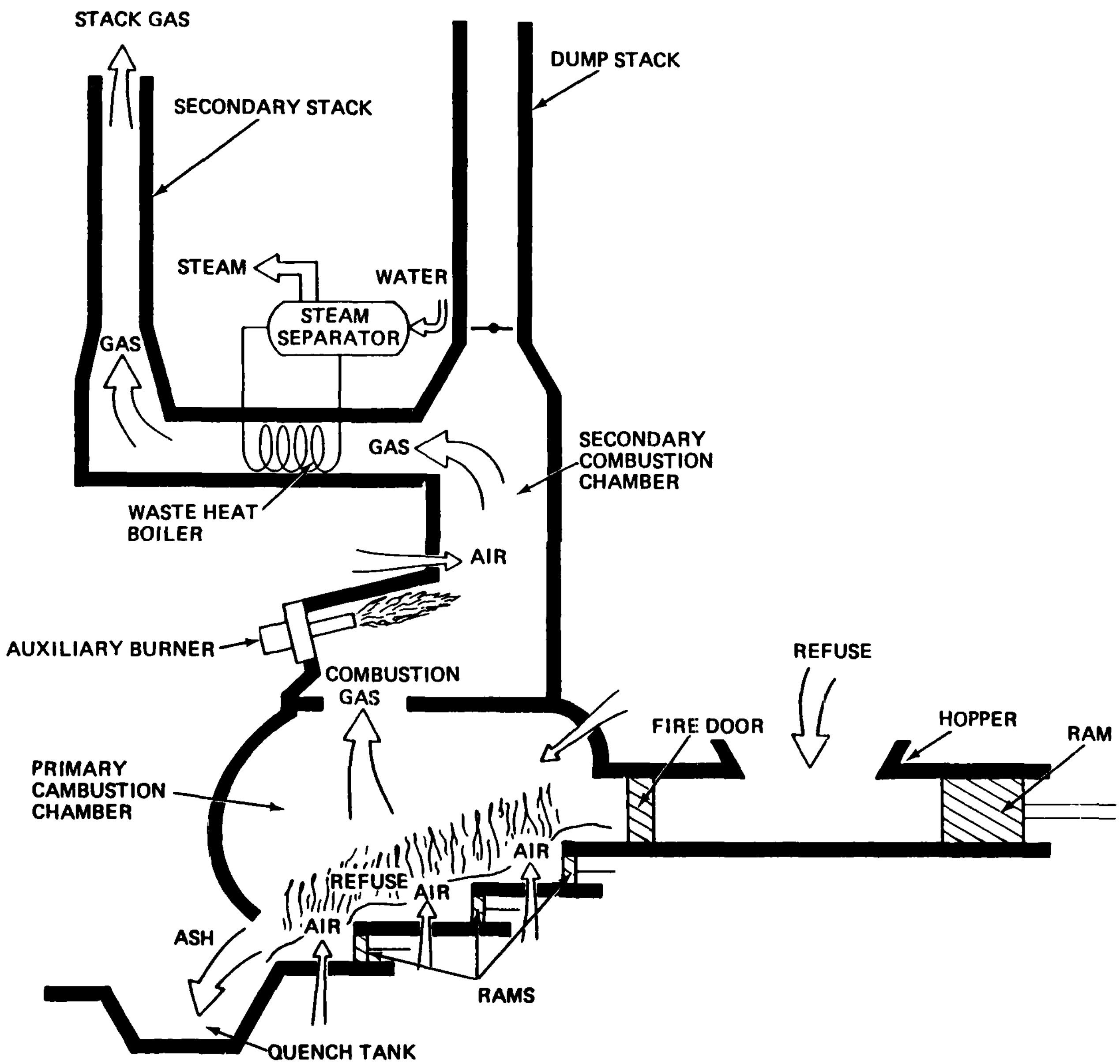


Figure S-4. Refuse-Fired Heating Plant

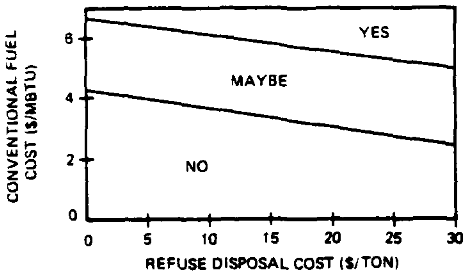
S 4. REFUSE-FIRED HEATING PLANT

DESCRIPTION: Solid waste can be utilized as a fuel to fire steam boilers. Besides saving energy, incineration will reduce the volume of solid waste by 90 percent, resulting in substantial savings in disposal costs. A wide variety of solid waste energy systems can be implemented at the activity. The three most common systems are: (1) modular waste heat incinerators, (2) field-erected, mass-fired systems, and (3) refuse-derived fuel (RDF) systems. RDF systems utilize shredders, air classifiers, magnetic separators, and other equipment to process refuse into a homogenous fuel which can be efficiently burned; these systems are marginally economical even in large-scale metropolitan applications. Field-erected, mass-fired systems have been successfully used for decades in Europe. A description of mass-fired systems appears in option P 4.

The most suitable refuse-fired system for low-pressure steam applications at Navy installations is the modular waste heat incinerator (see illustration on facing page). Startup costs are low because the modular units are shipped directly from the factory to the site. Modular incinerators are generally installed alongside a prefabricated refuse-handling building. The system operates as follows. Refuse is dumped on the floor of the building and is pushed by a front-end loader into a hopper. The refuse is then mechanically rammed into the primary combustion chamber of the incinerator. Partial combustion occurs in the primary chamber and is completed by an auxiliary burner in the secondary chamber. Relatively clear combustion gases are directed through a waste heat boiler where low-pressure steam is generated.

General design information on modular refuse-fired heating plants appears in two NCEL publications: TM 54-82-10 and CR 82.001. A refuse-fired heating plant is generally designed to supplement an existing conventional heating plant. The existing conventional plant is sized to provide the installation's entire steam requirement (see options S 1 through S 3). The refuse-fired plant is tied into the existing steam grid. When the refuse-fired plant generates steam, the central heating plant can cut back on its usage of conventional fuel, thereby resulting in energy savings. For maximum efficiency, the refuse-fired plant should operate on a 24-hour-a-day, 5-day-a-week schedule with a design steam generation rate that does not exceed the activity's minimum demand.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: This plant has substantial benefits in reduced disposal requirements for solid waste and a free source of energy. Detriments include: (1) relatively short operating experience with modular units, (2) questionable economics in comparison with conventional fuel systems, and (3) numerous operating and maintenance difficulties due to the heterogeneous nature of the fuel.

SURVEY DATA NEEDS:

- Annual tons of refuse generated at the activity
- Heating value of refuse
- Efficiency of central heating plant
- Minimum recorded steam demand
- Current disposal costs

PROCEDURE:

1. For a 5-day-a-week operation:

   Rated Capacity of Refuse-Fired Plant (tons per day or TPD) = $\frac{\text{Annual Tons of Refuse}}{260}$ x Redundancy Factor (1.5 to 2.0)

2. Provide more than one modular incinerator in the plant. For a plant with incinerators of equal size operating 24 hours a day:

   Rated Capacity of Each Incinerator (tons per hour or TPH) = $\frac{\text{Rated Capacity of Plant (TPD)}}{\text{(No. of Incinerators) x 24}}$

3. Annual Refuse Energy Input (MBtu/yr) = Annual Tons of Refuse x Heating Value of Refuse (3,000 to 6,000 Btu/lb)

4. Average Steam Generation (lb/hr) = Annual Refuse Energy Input (MBtu/yr) x Efficiency (0.4–0.6) x (0.146)

5. Conventional Fuel Savings (MBtu/yr) = Annual Refuse Energy Input (MBtu/yr) x $\frac{\text{Refuse Plant Efficiency (0.4 to 0.6)}}{\text{Conventional Plant Efficiency (0.75 to 0.80)}}$

GENERAL INFORMATION:

Modular Sizes Available: 5.1 to 100 TPD (24-hour operation)
Startup Cost: $0.5M to $1.0M tons per hour
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Skilled boiler plant operators, loader equipment operators, and maintenance personnel.
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta(E\ Conv)\ (DERF) + (\Delta D + O\&M_{Conv} - O\&M_{Refuse})\ (PYDF)}{C(PIF)}$$

where:

E_{conv} = Annual Conventional Fuel Cost Savings

$O\&M_{conv}$ = Reduction in Annual O&M Costs at the Conventional Heating Plant (due to reduced operations)

$O\&M_{refuse}$ = Annual O&M Costs at the Refuse-Fired Heating Plant

ΔD = Reduction in refuse disposal costs (due to refuse-fired heating plant operations)

SAMPLE CALCULATION:

Assumptions:

Central heating plant is an oil-fired system.
Efficiency of Central Heating Plant: 75%
Minimum Recorded Steam Demand: 12,000 lb/hr
Annual Tons of Refuse Generated at the Activity: 7,800 tons/year
Heating Value of Refuse: 4,500 Btu/lb
Refuse-Fired Plant Efficiency: 45%
Current Landfilling Cost: $10.00/ton
Startup Cost: $1.66M
$O\&M_{Conv}$: $0.0171M/yr
$O\&M_{Refuse}$: $0.275M/yr
D: $0.0546M/yr (7,800 tons/yr @ $10.00/ton) (0.70)

Fuel Saved: No. 6 fuel oil
Energy Cost: $4.14/MBtu
Escalation Rate: 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Rated capacity of refuse-fired plant} = \frac{\text{Annual Tons Refuse}}{260} \times \text{Redundancy Factor}$$

$$= \frac{7{,}800}{260} \times 1.66$$

$$= 49.8\ \text{TPD} = 2.08\ \text{TPH}$$

$$\text{Rated Capacity of Each Incinerator} = \frac{\text{(Rated Capacity of Plant)}}{\text{(No. of Incinerators)} \times (24)}$$

$$= \frac{49.8}{2 \times 24}$$

$$= 1.04\ \text{TPH}$$

Annual Refuse Energy Input = Annual Tons of Refuse x Heating Value of Refuse x 0.002

= (7,800) (4,500) (0.002)

= 70,200 MBtu/yr

Average Steam Generation = Annual Refuse Energy Input x Refuse Plant Efficiency x 0.146

= (70,200) (0.45) (0.146)

= 4,612 lb/hr (which is less than the minimum steam demand of 12,000 lb/hr)

CONVENTIONAL FUEL SAVINGS (MBtu/yr) =

$$\text{Annual Refuse Energy Input} \times \frac{\text{Refuse Plant Efficiency}}{\text{Conventional Plant Efficiency}}$$

$$= (70{,}200) \times \frac{(0.45)}{(0.75)}$$

= 42,120 MBtu/yr

NES (MBtu/yr) =

42,120 MBtu/yr

= 42,120 MBtu/yr

FUEL COST SAVINGS ($/yr) =

42,120 MBtu/yr x $4.14/MBtu

= $0.174 M/yr

SIR =

$$\frac{\$0.174M\ (20.05) + (\$0.0546M + \$0.0171M) - (\$0.275M)\ (9.524)}{\$1.66M\ (1)}$$

= 0.935

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ELECTRIC

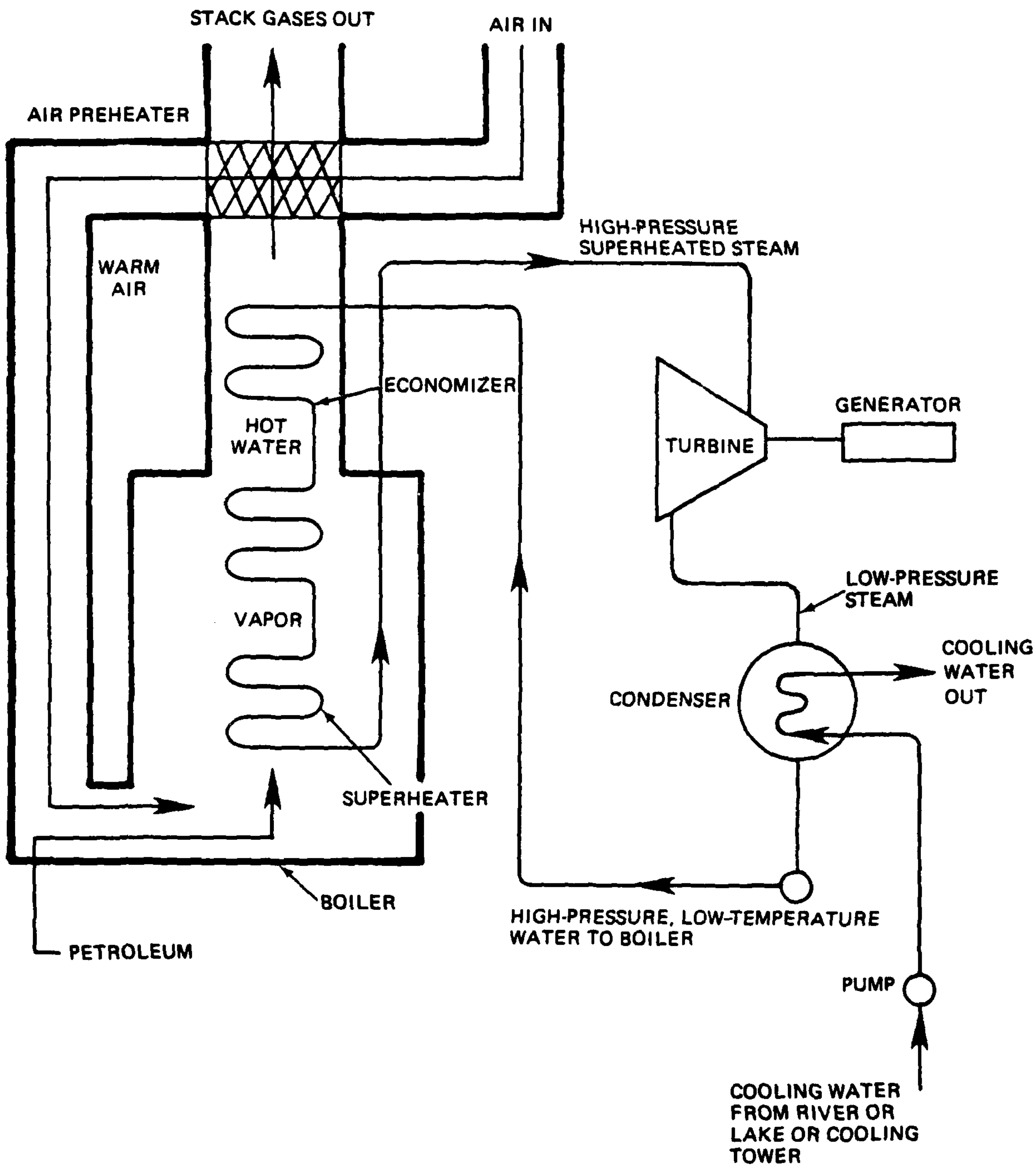


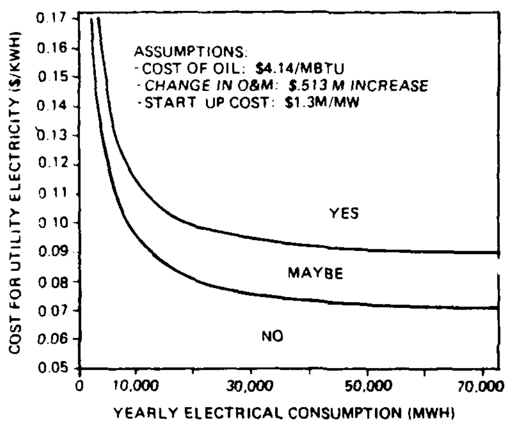
Figure P-1. Oil-Fired Electric Power Plant

P 1. OIL-FIRED ELECTRIC POWER PLANT

DESCRIPTION: Saving energy is not the objective of P 1. The objective is a reduction in energy cost (i.e. \$/kwh) (associated with high commercial utility rates) by building an on-site oil-fired electric power plant. Petroleum is commonly used to fire boilers in steam turbine power plants. High-pressure steam from the boilers drives turbines which in turn drive generators to provide electric power. Low-energy steam leaving the turbines is condensed and pumped back to the boilers, where it is heated into steam again; the cycle is then repeated. Condensing systems can use river water, a cooling pond, or cooling towers to reject waste heat. Exhausted combustion gases are treated to reduce particulate and sulfur oxide emissions.

Fuel oil and water are required. Power plants are frequently sited near large bodies of water for heat rejection. Small power plants have poor efficiencies of 28%-30%. They can be of interest only if the utility power costs are very high.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: In areas in which the cost of commercial electricity is high, the feasibility of providing electric power from an oil-fired plant should be examined. If there are oil-producing areas in the near vicinity, economic advantages could be achieved with lower delivery costs and assured fuel oil supply.

There are a number of detrimental factors. The price of fuel oil is subject to sharp increases and this is a variable factor which cannot be forecast with reasonable certainty. A high SIR at one point in time can rapidly become a low SIR. It is also detrimental that small power plants have a lower efficiency than large commercial generating plants, from 8 to 10 percent lower. Accordingly, energy conservation on a broad level is not being achieved. Whereas, if the shift were to coal burning this would not be as important as coal is relatively abundant.

SURVEY DATA NEEDS:

- Cost of commercial electrical power (\$/kwh)
- Total yearly electrical consumption (Mwh/yr)
- Cost of oil (\$/MBtu)

PROCEDURE:

1. Average Electrical Demand (Mwh/hr) =

$$\frac{\text{Annual Electrical Consumption (Mwh/yr)}}{\text{24 hr/day x 365 day/yr}}$$

2. Plant Size_{new} (Mw) =

$$\frac{\text{Average Electrical Demand}}{0.55}$$

3. Electrical Cost Savings (\$/kwh) =

(Annual Electrical Consumption (Mwh/yr)) x

$$\left[(1{,}000\ \text{kwh/Mwh} \times \$/\text{kwh}) - (11{,}600\ \text{Btu/kwh} \times \$/\text{MBtu})\right]$$

GENERAL INFORMATION:

Unit Sizes: 5 to 50 Mw
Startup Cost: \$1.3M/Mw
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Power plant operator, maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available On Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in Kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{elec}\,(DERF) - \Delta E_{oil}\,(DERF) + \Delta O\&M\,(PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Annual Electrical Consumption: 48,000 Mwh
Startup Cost: \$13.23M
Equipment Life: 25 years
Usage Factor: 0.55
Change in O&M: \$0.513M/yr (increase)
Fuel Saved: Electricity, Oil
Energy Cost: \$0.08/kwh, \$4.14/MBtu
Escalation Rate: 7% (electricity), 8% (oil)
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Average Electrical Demand} = \frac{48{,}000\ \text{Mwh/yr}}{24\ \text{hr/day} \times 365\ \text{day/yr}}$$

= 5.5 Mw

$$\text{Plant Size} = \frac{5.5\ \text{Mw}}{0.55} = 10\ \text{Mw}$$

NES (MBtu/yr) = 0

ELECTRICAL COST SAVINGS (\$/yr) =

$$(48{,}000\ \text{Mwh/yr}) \times \left[(1{,}000\ \text{kwh/Mwh} \times \$0.08/\text{kwh}) - (11.6\ \text{MBtu/Mwh} \times \$4.14/\text{MBtu})\right]$$

= \$1.53 M/yr

SIR =

$$\frac{\$3.84M\,(18.049) - \$2.31M\,(20.05) + (-0.513M)\,(9.524)}{\$13.23M\,(1)}$$

= 1.37

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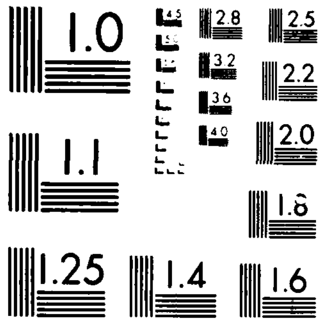

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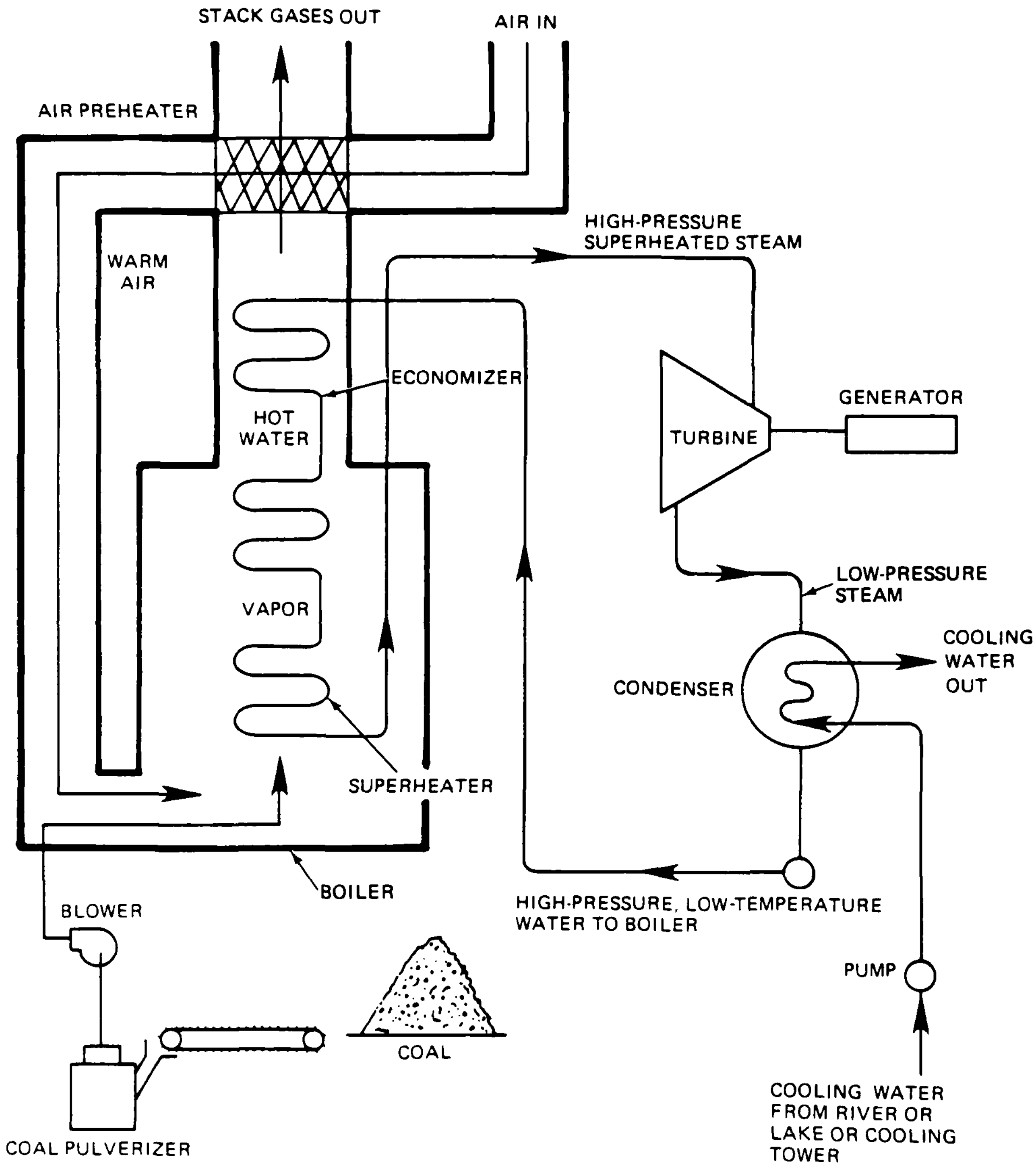
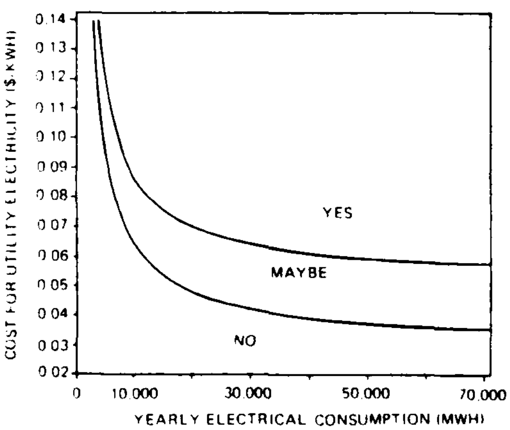


Figure P-2. Coal-Fired Electric Power Plant

DESCRIPTION: *Saving energy is not the objective of P 2.* The objective is a reduction in energy cost (i.e. \$/kwh) (associated with high commercial utility rates) by building an on-site coal-fired electric power plant. Coal is commonly used to fire boilers in steam turbine power plants. In future years, users of coal in power plants will increase dramatically due to the fuel's relatively low cost and plentiful domestic supply. In large utility boilers, coal is generally pulverized and blown into the furnace. High-pressure steam from the boilers drives turbines which in turn drive generators to provide electric power. Low energy steam leaving the turbines is condensed and pumped back to the boilers where it is heated into steam again; the cycle is then repeated. Condensing systems can use river water, a cooling pond, or cooling towers to reject waste heat. Stack gases from coal plants must pass through air pollution control equipment, such as scrubbers or electrostatic precipitators, before they can be released to the atmosphere.

A supply of coal and feedwater is required. A railroad spur is required for coal shipments and must be provided. Other requirements include a protected coal pile storage area, heat rejection provisions such as a nearby body of water, and a permitted site for ash disposal.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Coal-fired boilers appear to have benefits associated largely with the virtually inexhaustible coal resources of this country. However, there are detriments, which must be carefully considered, even though a high SIR can be obtained using this source of energy.

Transportation. The transportation of coal is presently by rail. Rail lines and spurs must be made available. Transport by rail may be relatively inexpensive initially. However, sharp increases in the rail rates often occur after a customer becomes dependent on the provided rail services. Such increases are not uncommon having been experienced by large cities as well as utilities.

Coal Handling and Refuse. These are not minor problems. Coal must be stored in quantity and handled in large amounts by equipment and people. Coal is attractive because of its availability, and low cost, not because of ease of handling. The residue ash must be handled and disposed of.

Pollution Control. Stack gases require control equipment to prevent air pollution. Scrubbers, electrostatic precipitators, and other devices are required. If these malfunction the plant must shut down. The pollution control is much more complex than for oil or gas-fired plants.

SURVEY DATA NEEDS:

- Cost of commercial electrical power (\$/kwh)
- Total annual electrical consumption (Mwh/yr)
- Cost of coal (\$/MBtu)

PROCEDURE:

1. Average Electrical Demand (Mwh/hr) =

$$\frac{\text{Annual Electrical Consumption (Mwh/yr)}}{\text{24 hr/day x 365 day/yr}}$$

2. Plant Size$_{new}$ (Mw) =

$$\frac{\text{Average Electrical Demand}}{0.55}$$

3. Electrical Cost Savings (\$/kwh) =

(Annual Electric Consumption (Mwh/yr)) [(1,000 kwh/Mwh x \$/kwh) - (11,600 Btu/kwh x \$/MBtu)]

GENERAL INFORMATION:

Sizes Available: 5 to 50 Mw
Startup Cost: \$1.5M/Mw
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Power plant operator, maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available On Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x 11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\frac{\Delta E_{elec}\text{ (DERF)} - \Delta E_{coal}\text{ (DERF)} + \Delta\text{O\&M (PYDF)}}{\text{C(PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Annual Electric Consumption: 48,000 Mwh
Startup Cost: \$15.19M
Equipment Life: 25 years
Usage Factor: 0.55
Change in O&M: \$0.62M (increase)
Fuel Saved: Electricity, coal
Energy Cost: \$0.08/kwh (electricity), \$1.902/MBtu (coal)
Escalation Rate: 7%, 5%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Average Electrical Demand $\dfrac{48{,}000 \text{ Mwh}}{24 \text{ hr/day} \times 365 \text{ day/yr}}$

$= 5.5$ Mw

Plant Size $= \dfrac{5.5 \text{ Mw}}{0.55}$

$= 10$ Mw

NES (MBtu/yr) = 0

ELECTRICAL COST SAVINGS (\$/yr) =

$(48{,}000 \text{ Mwh/yr}) \times \Big[(1{,}000 \text{ kwh/Mwh} \times \$0.08\text{/kwh}) -$

$(11.6 \text{ MBtu/Mwh} \times \$1.902\text{/MBtu})\Big]$

$= \$2.78$ M/yr

SIR =

$$\frac{\$3.84M\ (18.049) - \$1.06M\ (14.777) + (-\$0.62M)(9.524)}{\$15.19M\ (1)}$$

$= 3.14$

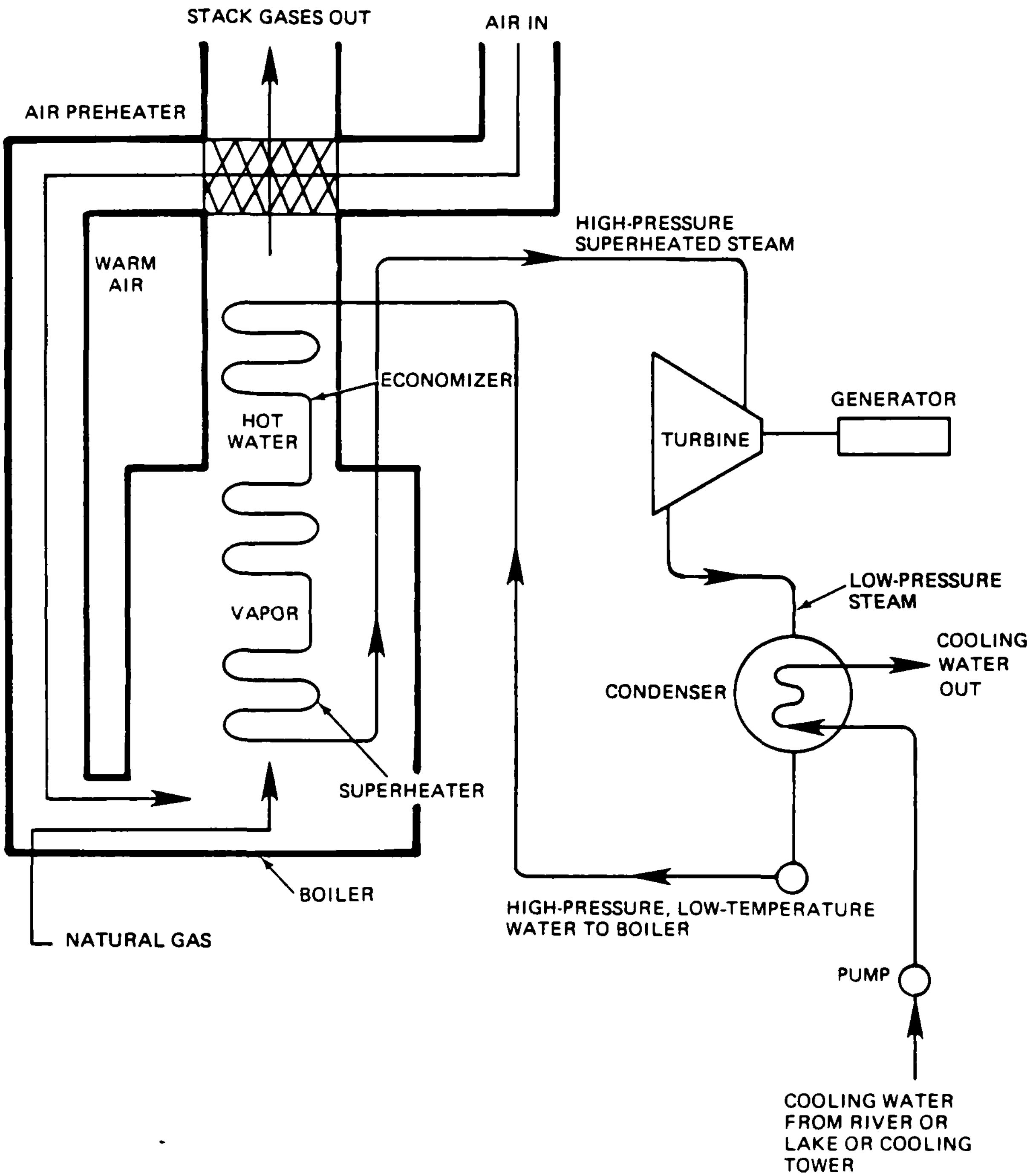
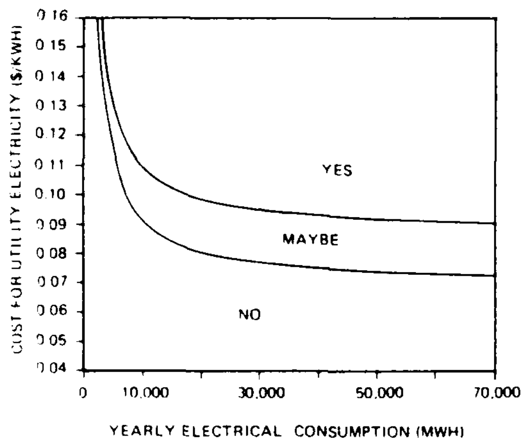


Figure P-3. Natural Gas-Fired Electric Power Plant

P 3. NATURAL GAS-FIRED ELECTRIC POWER PLANT

DESCRIPTION: *Saving energy is not the objective of* P 3. The objective is a reduction in energy costs (i.e. $/kwh) (associated with high commercial utility rates) by building an on-site natural gas-fired electric power plant. Natural gas is commonly used to fire boilers in steam turbine power plants. High-pressure steam from the boilers drives turbines which in turn drive generators to provide electric power. Low energy steam leaving the turbines is condensed and pumped back to the boilers where it is heated into steam again; the cycle is then repeated. Condensing systems can use river water, a cooling pond, or cooling towers to reject waste heat. Natural gas is clean-burning and has a lower environmental impact than other fossil fuels. The price of natural gas is expected to rise rapidly in response to deregulation legislation.

FEASIBILITY REQUIREMENT:



Graph Assumptions:
Cost of Gas: $6.00/MBtu, ΔO&M = $0.422M increase, C = $1.2M/Mw, life = 25 years

BENEFITS/DETRIMENTS: Gas-fired electric power plants are an ideal source of power. Natural gas burns cleanly and has minor air-pollution problems and no residue. There is less boiler maintenance required as the fire-sides of the generating tubes remain clean and do not become encrusted with combustion residue. Gas is available in large quantities and conveniently provided by pipeline to any desired location.

Gas prices, however, for various reasons are not in the free marketplace. Despite a glut of natural gas, the costs have been high, and in fact, have continued to rise. Utilities have suffered severe losses in contracts that were voided at the whim of the supplier. Entire areas have shifted from gas to coal burning as a result of factors of this nature.

SURVEY DATA NEEDS:

- Cost of commercial power
- Total yearly electrical consumption

PROCEDURE:

1. Average electrical demand (Mwh/hr) =

$$\frac{\text{Annual Electrical Consumption (Mwh/yr)}}{24 \text{ hr/day} \times 365 \text{ day/yr}}$$

2. Plant Size$_{new}$ (Mw) =

$$\frac{\text{Average Electrical Demand}}{0.55}$$

3. *Electrical Cost Savings ($/kwh)* =

$$(\text{Annual Electric Consumption (Mwh/yr)})\left[(1{,}000 \text{ kwh/Mwh} \times \$/\text{kwh}) - (11{,}600 \text{ Btu/kwh} \times \$/\text{MBtu})\right]$$

GENERAL INFORMATION:

Sizes Available: 5 to 50Mw
Startup Cost: $1.2M/Mw
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Power plant operators, maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,600 btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta E_{elec}\,(\text{DERF}) - \Delta E_{coal}\,(\text{DERF}) + \Delta\text{O\&M}\,(\text{PYDF})}{C(\text{PIF})}$$

SAMPLE CALCULATION:

Assumptions:
Annual Electrical Consumption: 48,000 Mwh
Startup Cost: $12.15M (estimate)
Equipment Life: 25 years
Usage Factor: 0.55
Efficiency: 28%
Change in O&M: $0.422M (increase)
Fuel Saved: Electricity, gas
Energy Cost: $0.08/kwh, $6.00/MBtu
Escalation Rate: 7%, 8%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

$$\text{Average Electrical Demand} = \frac{48{,}000 \text{ Mwh}}{24 \text{ hr/day} \times 365 \text{ day/yr}}$$

$$= 5.5 \text{ Mw}$$

$$\text{Plant Size} = \frac{5.5 \text{ Mw}}{0.55}$$

$$= 10 \text{ Mw}$$

NES (MBtu/yr) = 0

ELECTRICAL COST SAVINGS ($/yr) =

$$(48{,}000 \text{ Mwh/yr}) \times \left[(1{,}000 \text{ kwh/Mwh} \times \$0.08 \text{ kwh}) - (11.6 \text{ MBtu/Mwh} \times 6.00/\text{MBtu})\right] = \$0.50\text{M/yr}$$

SIR =

$$\frac{\$3.84\text{M}(18.049) - \$3.34\text{M}(20.050) + (-\$0.422\text{M})(9.524)}{\$12.15\text{M }(1)}$$

$$= -0.14$$

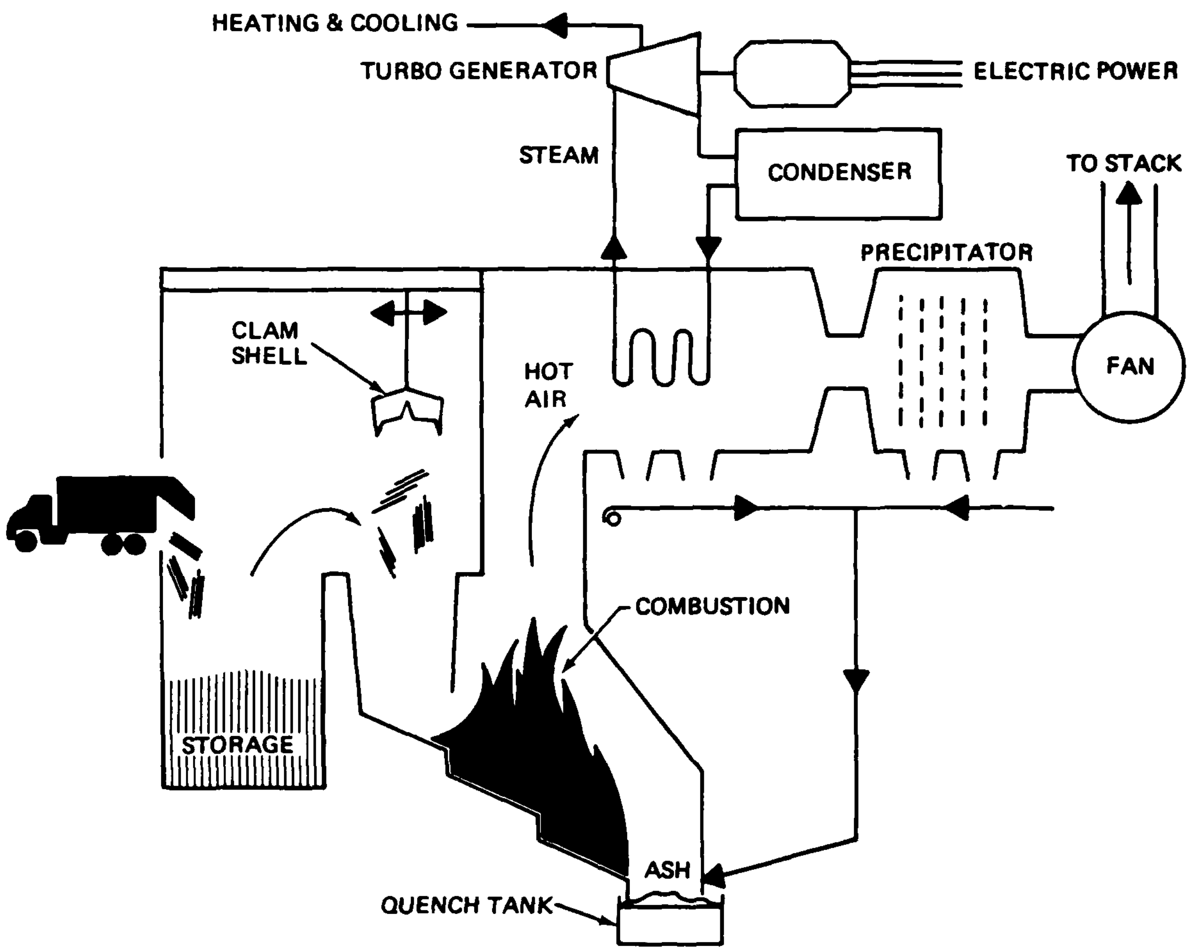


Figure P-4. Refuse-Fired Electric Power Plant

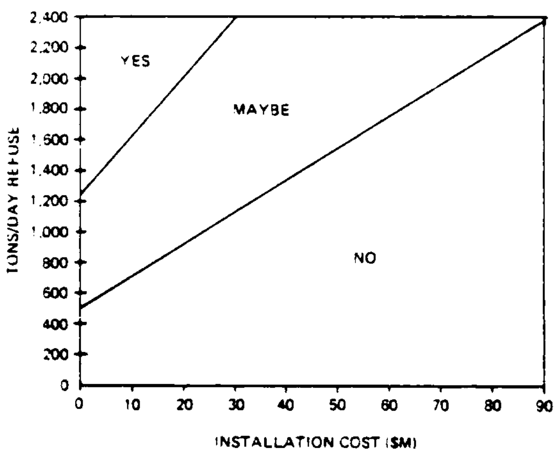
P 4. REFUSE-FIRED ELECTRIC POWER PLANT

DESCRIPTION: Solid waste can be utilized as a fuel to fire boilers in steam turbine power plants (although low-pressure steam production is more common). Besides energy savings, incineration can reduce the volume of solid waste by 90% and the tonnage by 70%, resulting in substantial savings in disposal costs. A wide variety of solid waste energy systems can be implemented such as field-erected, mass-fired systems and refuse-derived fuel (RDF) systems. RDF systems utilize shredders, air classifiers, magnetic separators, and other equipment to process refuse into a homogeneous fuel which can be efficiently burned.

The illustration shows a field-erected, mass-fired facility. Refuse is dumped into a storage pit. An overhead clamshell crane picks up a selective quantity of refuse and dumps it into a hopper. The refuse is then moved by a grate through the furnace. Underfire and overfire air aid in combustion of the refuse. Waterwall tubes absorb the radiant heat of the furnace, and convective tubes absorb captive heat from the combustion gases. The resulting high-pressure steam drives turbines, is condensed, and is pumped back to the boilers where it is heated into steam again. Stack gases are directed to air pollution control equipment such as electrostatic precipitators or scrubbers before release to the atmosphere.

To date, power generated by refuse firing has not been economical in activity-sized systems. Considerable experimentation with various kinds of refuse-fired systems is currently being pursued throughout the country. Navy activities should avoid being misled by exaggerated manufacturer's claims.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: A refuse-fired power plant has substantial benefits in reduced disposal requirements for solid waste and a free source of energy. Detriments include:

1. Questionable economics in comparison with conventional fuel systems.
2. Potential trouble in matching power demand.
3. Lack of good operating data on most systems.
4. Numerous operating and maintenance difficulties due to the heterogeneous nature of the fuel.
5. Potential problem with hazardous air emissions.

SURVEY DATA NEEDS:

- The amount of refuse which is available on a daily basis in tons.
- Current costs of collection and disposal of refuse on an annual basis, including disposal fees.
- The local cost of utility power.
- The estimated hours of full plant capacity per year operation.

PROCEDURE:

1. For a 5-day-a-week, 24-hour-a-day operation:

$$\text{Rated Capacity of Refuse-Fired Plant (tons per day or TPD)} = \left[\frac{\text{Annual Tons of Refuse}}{260} \times \text{Redundancy factor (1.5 to 2.0)}\right]$$

2. Provide more than one incinerator in the plant. For a plant with equally sized incinerators operating 24 hours a day:

$$\text{Rated Capacity of Each Incinerator (TPD)} = \frac{\text{Rated Capacity of Plant (TPD)}}{\text{Number of Incinerators}}$$

3. $$\text{Annual Refuse Energy Input (MBtu/yr)} = \left[\text{Annual Tons of Refuse (tons/yr)} \times \text{Heating Value of Refuse (3,500-6,000 Btu/lb)} \times \frac{2{,}000 \text{ lb ton}}{10^6 \text{ Btu/MBtu}}\right]$$

4. $$\text{Average Power Generation (Mw)} = \left[\frac{\text{Annual Refuse Energy Input (MBtu/yr)} \times 10^6 \frac{\text{Btu}}{\text{MBtu}} \times \text{Efficiency (0.20-0.30)}}{3{,}413 \frac{\text{Btu}}{\text{kwh}} \times 10^3 \frac{\text{kw}}{\text{Mw}} \times 6{,}240 \frac{\text{hr}}{\text{yr}}}\right]$$

5. Assuming All Power Generated is Used:

$$\text{Annual Utility Savings (Mwh/yr)} = \left[\text{Average Power Generation (Mw)} \times 6{,}240 \frac{\text{hr}}{\text{yr}}\right]$$

GENERAL INFORMATION:

Sizes Available: 150 to 1,500 TPD
Startup Cost: \$60K to \$100K per TPD (\$2.0-3.5M/Mw)
Equipment Life: 25 years
Skill Level of Personnel Required: Power plant operators, maintenance personnel, and solid waste handlers
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test & Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) + (Electrical Energy Savings (in kwh/yr) x 11,500 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

SIR =

$$\frac{\Delta(E_{old})\ (DERF) + (\Delta D - O\&M_{Refuse})(9.524)}{C(PIF)}$$

where:

ΔE_{old} = Annual Utility Savings due to Power Plant Operation.

ΔD = Reduction in Annual Refuse Disposal Costs due to Refuse Incineration.

$O\&M_{refuse}$ = Annual O&M Costs at the Refuse-Fired Power Plant.

SAMPLE CALCULATION:

Assumptions:

Refuse-Fired Power Plant Operating Hours: 5 days a week, 24 hrs a day.
Annual Tons of Refuse to be Incinerated at Plant: 91,000 tons/year
Heating Value of Refuse: 5,000 Btu/lb
Efficiency of Refuse-to-Power Conversion: 0.23
Current Landfilling Costs: $5.00/ton
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7% (electricity)
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Rated capacity of Refuse-Fired Plant $= \frac{\text{Annual tons Refuse}}{260}$

x Redundancy Factor

$$= \frac{91,000}{260} = 350 \text{ TPD}$$

Rated Capacity of Each Incinerator $= \frac{\text{Rated Capacity of Plant}}{\text{Number of Incinerators}}$

$$= \frac{466}{4} = 117 \text{ TPD}$$

Annual Refuse Energy Input = Annual Tons of Refuse x

Heating Value of Refuse $\times \frac{2,000}{10^6}$

$$= 91,000 \times 5,000 \times \frac{2,000}{10^6} = 910,000 \text{ MBtu/yr}$$

Average Power Generation =

Annual Refuse Energy Input $\times \frac{10^6 \times \text{Efficiency}}{3413 \times 10^3 \times 6240}$

$$= 910,000 \times \frac{10^6 \times 0.23}{3413 \times 10^3} \times 6,240 = 9.83$$

Assume 70 percent of power can be used:

ELECTRICAL SAVINGS (Mwh/yr) =

$9.83 \times 6,240 \times 0.7 = 42,900$ Mwh/yr

ELECTRICAL COST SAVINGS (ΔE_{old}) ($/kwh)

$$= 42,900 \text{ Mwh/yr} \times 1,000 \times \frac{\$0.08}{\$0.319M}$$

= $3.43M

ΔD = $\underline{(91,000 \text{ tons/yr})(0.7)(\$5.00/\text{ton})}$

= 0.319M in Disposal Cost Savings for Tonnage Reduction of 70 Percent

$O\&M_{Refuse}$ = $3.90M/yr

C = (466 TPD) ($90K/TPD) = $41.94M

NES $= 4.29 \times 10^7 \text{ kwh/yr} \times 11,600 \frac{\text{Btu}}{\text{kwh}} \times 10^{-6} \frac{\text{MBtu}}{\text{Btu}}$

$= 4.98 \times 10^5$ MBtu/yr

SIR $$= \frac{(\$3.43M)(18.049) + (\$.319M - \$3.90M)(9.524)}{\$41.94M\ (1)}$$

= 0.663

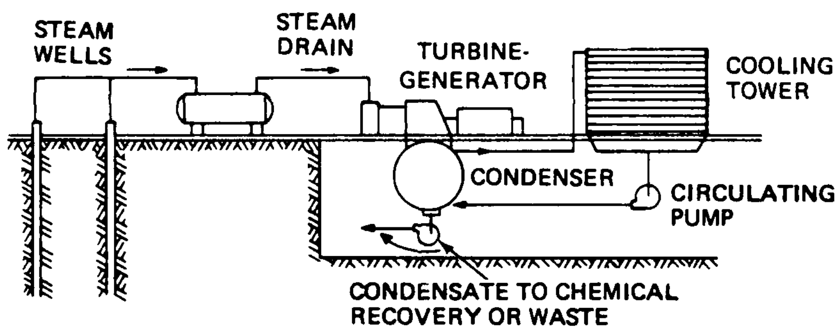


Figure P-5. Geothermal Electric Power Plant

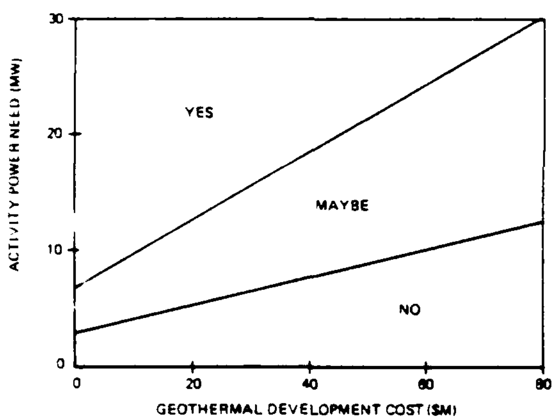
P 5. GEOTHERMAL ELECTRIC POWER PLANT

DESCRIPTION: The Navy has recognized the geothermal potential and its limitations. There is an ongoing Navy program to examine all the practical alternatives and establish geothermal electric power plants where it is possible. NWCTP 6238 "Navy Geothermal Plan," October 1980, page 4, lists these sites:

1. NWC (China Lake) COSO Geothermal Area
2. NAVSTA Adak, Alaska
3. NAS Fallon, Nevada
4. NAVMAG Lualualei, Hawaii
5. Imperial Valley, California

The plant type and size depends on the needs of the site, availability of surrounding markets for excess power, and the nature of the geothermal fluid. Advances in technology, especially in materials and in turbines have been significant in recent years. Bi-phase turbines are now available which can generate power from both the liquid and steam phases of superheated water. Flexible systems such as these can handle mixtures of steam and liquid and operate successfully under variable conditions. Because these power systems have commercial applications, they have been developed in reasonable sizes that are relatively easy to relocate.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Since geothermal power does not use fossil fuels, its use is optimum. No gaseous or solid waste pollutants result. The power source is ideal. Geothermal power depends on the site which can vary in its characteristics. However, relocatable power units can be used in a practical manner in the small sizes of interest, 10 Mw or less.

SURVEY DATA NEEDS:

- Research geothermal area potential
- Estimate the cost of geothermal development
- Select optimum size plant
- Compare available power units with geothermal characteristics
- Commercial power costs
- Plant size (Mw)

PROCEDURE:

1. Electrical Savings (kwh/yr) =

$$\frac{\text{Hours Operation}}{\text{Year}} \times \frac{1{,}000\ \text{kw}}{\text{Mw}} \times \frac{\text{Plant}}{\text{Size}}$$

GENERAL INFORMATION:

Sizes Available: 2 to 10 Mw
Startup Cost: $1,500 per kw
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Annual O&M: $0.7M to $2.0M increase

Skill Level of Personnel Required: Electric power-plant operators, maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$\text{SIR} = \frac{E_{Elec}(\text{DERF}) - E_{Stm}(\text{DERF}) - \Delta\text{O\&M (PYDF)}}{\text{C (PIF)}}$$

SAMPLE CALCULATION:

Assumptions:
Size Used: 10 Mw
Startup Cost: $15M
Operating Hours: 4,818 hr/yr
Change in O&M: $2.0M increase
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

4,818 hr/yr x 1,000 kw/Mw x 10 mw

$= 4.818 \times 10^7$ kwh/yr

NES (MBtu/yr) =

$0 + 4.818 \times 10^7$ kwh/yr x 11,600 Btu/kwh

$= 5.59 \times 10^5$ MBtu/yr

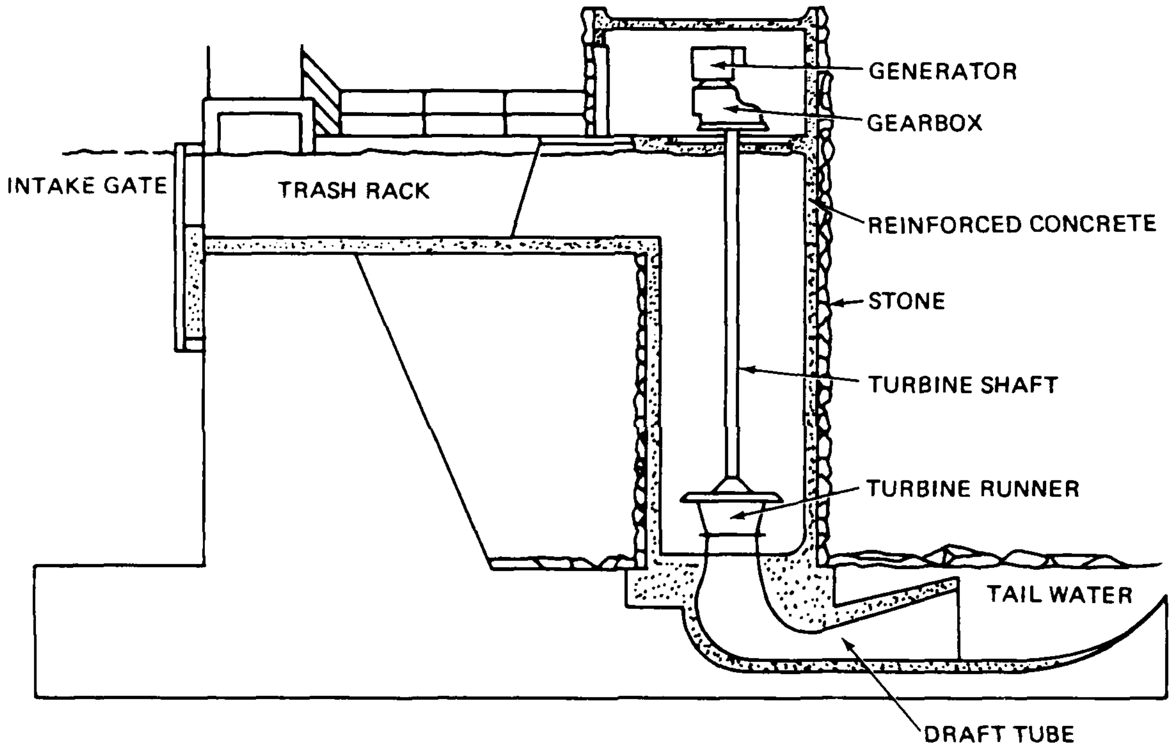
ELECTRICITY COST SAVINGS ($/yr) =

4.818×10^7 kwh/yr x $0.08/kwh

= $3.85M/yr

$$\text{SIR} = \frac{\$3.85\text{M } (18.049) - \$0 - \$2.0\text{M } (9.524)}{\$15\text{M } (1)}$$

= 3.36



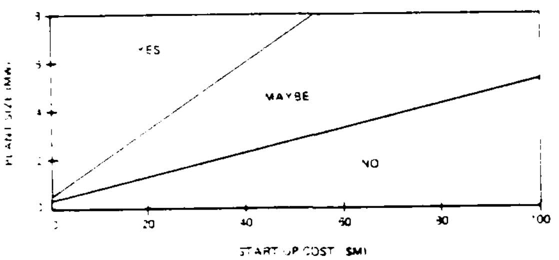
HYDROELECTRIC POWER PLANT

Figure P-6. Small-Scale Hydroelectric Power Plant

DESCRIPTION: Small hydroelectric plants are defined as having less than 15 Mw capacity with dams less than 65 feet high and impounding less than 500 acres. The systems consist of a dam and penstock that feed water to a hydraulic turbine. The turbine drives an electric generator. Additional control and power conditioning equipment are used.

A hydroelectric plant is site-specific. One must start out with the water that is there most of the time, then suit the turbine and generator to the source and location. A small project will be based on "run-of-river" water availabilities.

FEASIBILITY REQUIREMENT:



BENEFITS/DETRIMENTS: Hydroelectric power is essentially solar energy in the form of rainfall. The advantage of hydroelectricity is that it is free from air and water pollution and once the initial investment is made, electrical power is essentially free, except for operation and maintenance costs. Hydroelectric power in itself has relatively little environmental effect, but the damming of rivers or streams can have a larger ecological impact. Other considerations include:

1. Existing dams cannot be presumed to be sound and retrofits can be difficult or impossible.

2. Water flowrates must be verified with weather service or other sources of data.

SURVEY DATA NEEDS:

- River flowrate
- Dam head

PROCEDURE:

1. Establish flowrate of river, lake or dam.
   - Flow data for stream or river may be available through government agencies or may be calculated.
   - To calculate flowrate, establish cross-sectional area of river and measure water velocity between two points along river. Measurement should be made using a dye dropped into middle of river and measuring the time required to cover a measured distance. Average flowrates should be verified using rain data available from the weather services.

A = Average Cross-sectional Area of River = $\frac{A_1 + A_2}{2}$

V = Velocity of Stream (ft/sec) = $\frac{D}{T}$ x 0.8

T = Time Required for Dye to Travel Distance (sec)

[illegible]

[illegible]

[illegible]

2. Estimate "head" (Height (H), in ft) of completed dam.
   - Rough estimates of head may be calculated from topography maps available through the U.S. Geological service or through rough survey using hand level and rod.

3. Calculate potential generator size.

   Generator Size (kw) = 0.167 x Q x H

4. Calculate electrical savings from hydroelectric power (kwh/yr) =

   Generator Size (kw) x hours of operation/yr

GENERAL INFORMATION:

Sizes Available: 2 kw to 15 Mw
Startup Cost: (new dam) \$4,000/kw
(old dam) \$2,000/kw
Annual O&M: \$0.25M/Mw
Equipment Life: 25 years
Replacement Cost: Same as startup cost
Skill Level of Personnel: Electric power plant operators and maintenance personnel

LEVEL OF DEVELOPMENT:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION

$$SIR = \frac{\Delta E_{elec}\ (DERF) - \Delta O\&M_{hydro}\ (9.524)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Size: 2 Mw
Startup Cost: \$8M (new dam)
Annual O&M: \$0.50M
Operating Hours: 4,818/yr
Head of Dam: 50 ft
River Cross Sectional Area: 48 ft^2
Flowrate of River: 5 ft/sec
Fuel Saved: Electricity
Energy Cost: \$0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

Flowrate of river (Q) =

A x V

= 48 ft^2 x 5 ft/sec (by dye method)

= 240 ft^3/sec

Head of dam (H) = 50 ft given

Generator Size (kw) = 0.167 x Q x H

= 0.167 x 240 x 50

= 2,004 kw

= 2.0 x 10^3 kw

Electrical Savings (kwh/yr) =

$4{,}818 \text{ hr/yr} \times 2.0\ (10^3) \text{ kw}$
$= 9.6 \times 10^6 \text{ kwh}$

NES (MBtu/yr) =

$4{,}818 \text{ hr/yr} \times 2.0\ (10^3) \text{ kw} \times$

$\frac{11{,}600 \text{ Btu}}{\text{kwh}} \times \frac{\text{MBtu}}{10^6 \text{Btu}} = 1.1\ (10^5) \text{ MBtu/yr}$

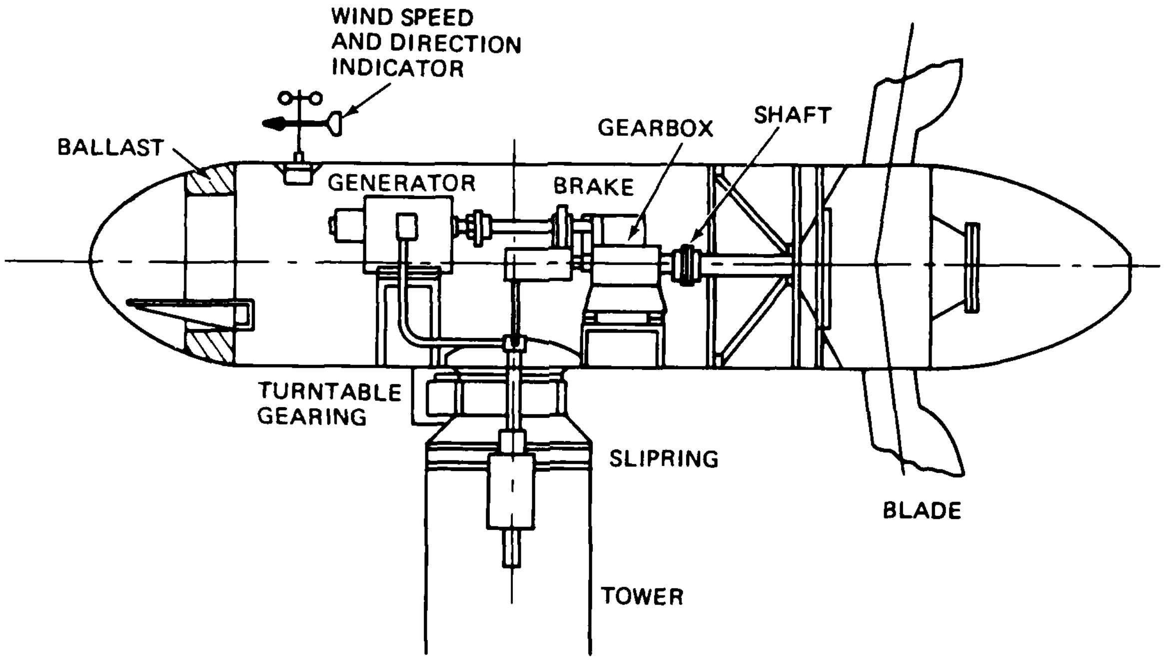
ELECTRICAL COST SAVINGS ($/yr) =

$9.6 \times 10^6 \frac{\text{kwh}}{\text{yr}} \times \$0.08/\text{kwh}$

$= \$0.77 \text{ M/yr}$

$$SIR = \frac{7.7\ (10^5)(18.049) - 5.0(10^5)(9.524)}{8(10^6)\ (1)}$$

$= 1.19$



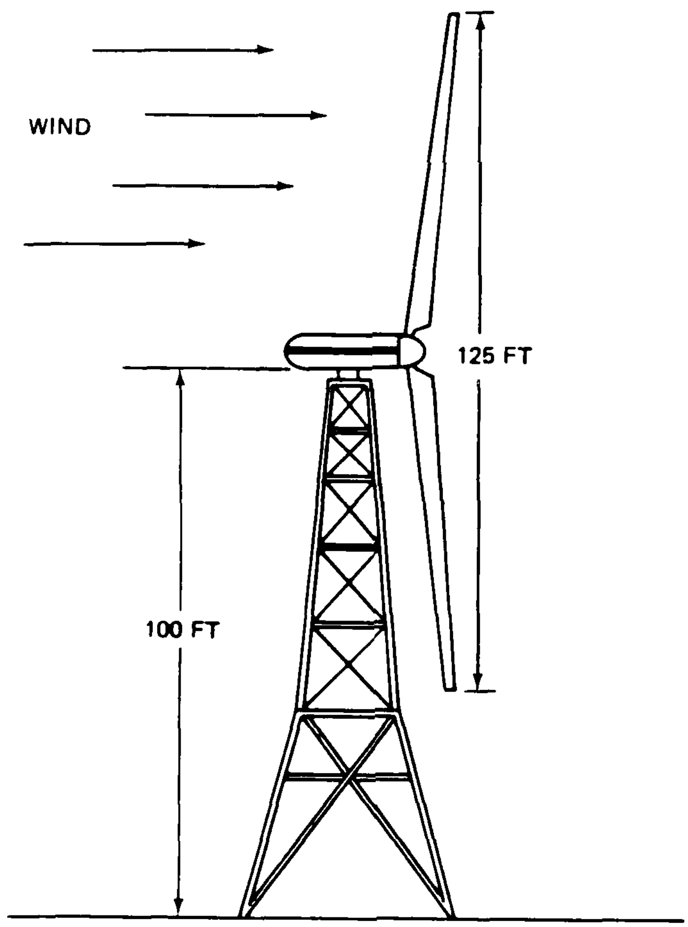


Figure P-7. Wind-Generated Electricity

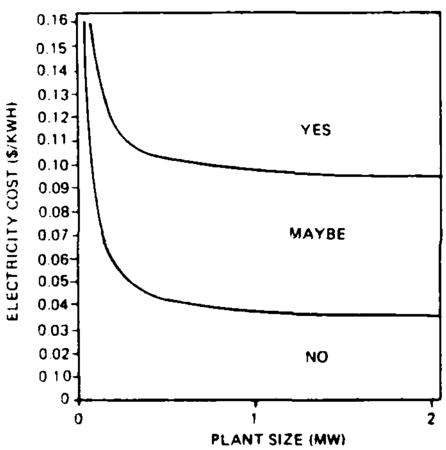
DESCRIPTION: The kinetic energy of winds can be converted to electric power using wind turbines. Large capacity machines usually consist of two propeller-like blades connected to a hub. When the wind blows with sufficient velocity, the blades spin, turning a generator via a transmission. The speed of the machine is governed by controlling blade pitch. The windmill is positioned in the wind using an electric drive to rotate the head atop the tower. The following information is pertinent.

1. The wind follows daily, monthly, and yearly patterns which can be roughly characterized.

2. For a cost effective wind machine today, average windspeeds of at least 10 mph are required. The available power in the wind varies as the cube of the windspeed.

3. Utilities are required by law to buy electricity (over what the facility needs) from independent producers at "avoided cost." This is the cost that they would otherwise pay to generate the power with their most expensive fuel. (The avoided cost has been running 5.3¢ to 7c/kwh of electricity.)

FEASIBILITY REQUIREMENT:



Graph Assumptions: 4,818 hours/yr; O&M = $50K increase; life expectancy = 25 years; cost (C) = $4,000/kw

BENEFITS/DETRIMENTS: Wind energy is completely cost-free and large wind farms are being commercially used. However, before serious consideration is given to a program for wind-generated electricity, the following should be kept in mind.

1. The average output of a wind farm is about 20% of its rated capacity.

2. Wind energy's strong point is not reliability, but its overall contribution to energy conservation.

3. A strong, prevailing wind of adequate wind speed is available in few locations.

SURVEY DATA NEEDS:

- Measure potential site winds over an adequate period of time using a wind odometer and determine wind speed.

- Verify results with a nearby weather station.

PROCEDURE:

1. Determine site wind energy available.

2. Check costs of available commercial wind machines which meet site requirements.

3. Plan wind farm of largest possible units as their installed cost is lowest.

4. Electrical Savings (kwh/yr) =

   Operating hr/year x Plant Size (mw) x 1,000 kw/mw

GENERAL INFORMATION:

Sizes Available: 0.5 to 1.5 Mw
Startup Cost: $4,000/kw
Replacement Cost: $2,000/kw
Equipment Life: 25 years
Skill Level of Personnel Required: Shop mechanic and electrician
Annual O&M: $50K increase
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	
Approved for Service	
Available on Market	x

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr):

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{Elec}(DERF) - \Delta O\&M_{wind}(PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Size Plant: 1 Mw
Startup Cost: $4M
Operating Hours: 4,818 hr/yr
Change in O&M: $50K
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

4,818 hr/yr x 1 Mw x 1,000 kw/Mw

= 4.818 x 10^6 kwh/yr

NES (MBtu/yr) =

0 + 4.818 x 10^6 kwh/yr x 11,600 Btu/kwh

= 5.59 x 10^4 MBtu/yr

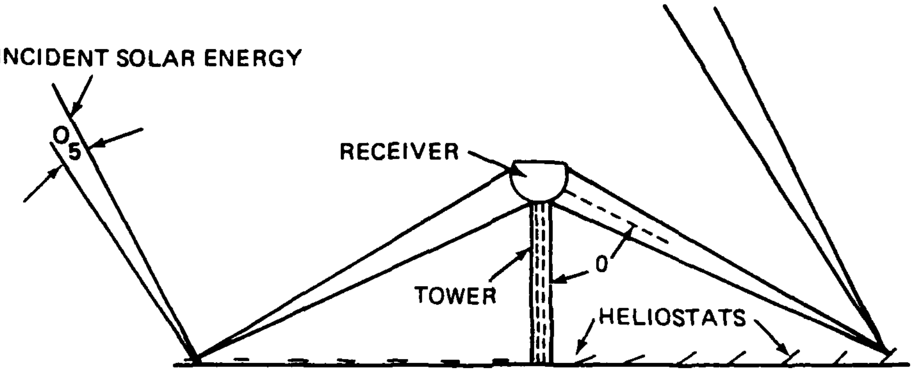
ELECTRICITY COST SAVINGS ($/yr) =

4.818 x 10^6 kwh/yr x $0.08/kwh

= $0.385M/yr

$$SIR = \frac{\$0.385M\ (18.049) + (-\$0.05M)\ (9.524)}{\$5M\ (1)}$$

= 1.62



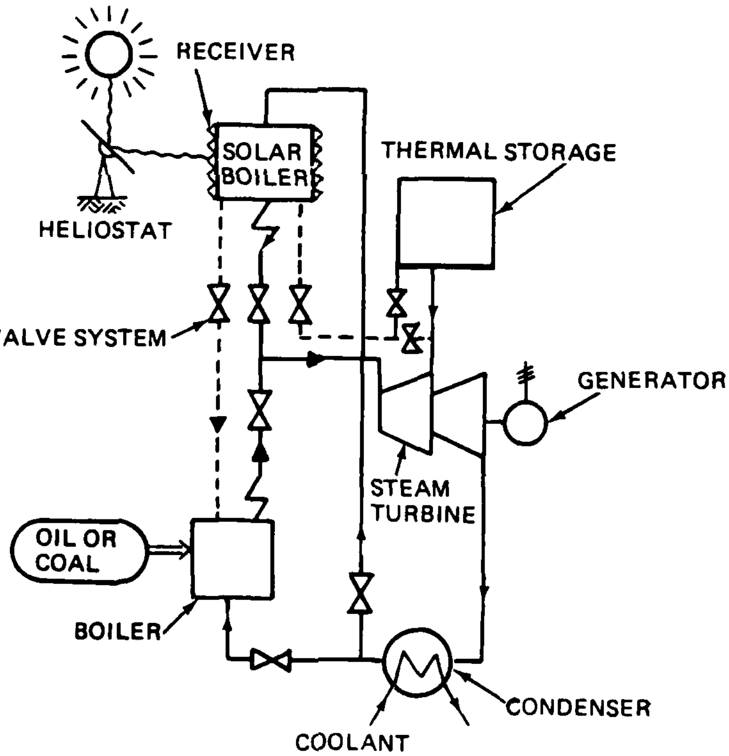
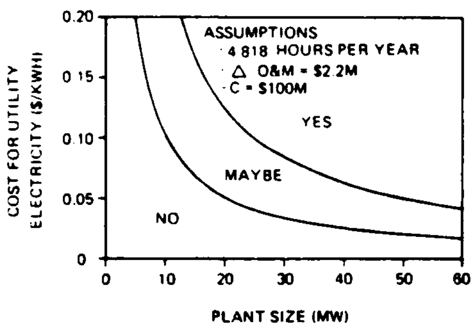


Figure P-8. Solar Electric Power Plant

P 8. SOLAR ELECTRIC POWER PLANT

DESCRIPTION: An experimental solar electric power plant has been built in the California desert. The plant consists of a field of computer-controlled mirrors which track the sun, reflecting its direct radiation onto a receiver mounted atop a tower. Heat from this receiver is transferred via a high temperature fluid to a heat exchanger to produce steam. Steam then drives a turbine to generate electricity. Storage systems may be employed to store heat during daylight hours for use at night.

FEASIBILITY REQUIREMENT:



BENEFIT/DETRIMENTS: The startup costs are very high. Southern California Edison spent $100 million on a 10 Mw plant near Barstow, CA. This plant is located in an area with virtually perfect weather conditions. For example:

- Warm climate
- Year-round sunshine
- Low haze and pollution
- Large available land area

Few Navy activities have locations with applicable weather conditions. However, for those activities that do, the energy is unlimited and fossil fuel savings are great.

SURVEY DATA NEEDS:

- Degree days
- Average sunshine
- Clearness of atmosphere
- Availability of land area that is smooth
- Hours operation/yr

PROCEDURE:

1. Make survey.
2. Check cost effectiveness of solar-power generation:
3. Electrical Savings (kwh/yr) =

   Operating hr/yr x Plant Size (Mw)

   x 1,000 kw/Mw

GENERAL INFORMATION:

Sizes Available: 10 to 50 Mw
Startup Cost: $100M to $300M
Replacement Cost: Same as startup cost
Equipment Life: 25 years
Skill Level of Personnel Required: Power plant operation and maintenance personnel
Level of Development:

Basic Research Underway	
Prototype Being Tested	
Operational Test and Evaluation Underway	x
Approved for Service	
Available on Market	

NATIONAL ENERGY SAVINGS (NES) (in Btu/yr)

NES = Hydrocarbon Fuel Savings (in Btu/yr) +

(Electrical Energy Savings (in kwh/yr) x

11,600 Btu/kwh)

ECONOMIC ANALYSIS EQUATION:

$$SIR = \frac{\Delta E_{elec}\ (DERF) + \Delta O\&M\ (PYDF)}{C(PIF)}$$

SAMPLE CALCULATION:

Assumptions:
Size: 10 Mw
Startup Cost: $100M
Operating Hours: 4,818 hr/yr
Change in O&M: $2.2M/yr
Fuel Saved: Electricity
Energy Cost: $0.08/kwh
Escalation Rate: 7%
Annual Discount Rate (R): 10%

Calculations follow from the procedure section:

ELECTRICAL SAVINGS (kwh/yr) =

4,818 hr/yr x 10 Mw x 1,000 kw/Mw

$= 4.818 \times 10^7$ kwh/yr

NES (MBtu/yr) =

$0 + 4.818 \times 10^7$ kwh/yr x 11,600 Btu/kwh

$= 5.59 \times 10^5$ MBtu/yr

ELECTRICITY COST SAVINGS ($/yr) =

4.818×10^7 kwh/yr x $0.08/kwh

= $3.854M/yr

$$SIR = \frac{\$3.854M\ (18.049) + (-\$2.2M)\ (9.524)}{\$100M\ (1)}$$

= 0.49

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SD 1. CLIMATE-BASED FACTORS FOR HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) CALCULATIONS

SD 1-1. GENERAL INFORMATION

Many factors affecting the magnitude of energy savings achievable from conservation programs are dependent on location, climate, or building design and load characteristics. The determination of these constant factors is discussed in this section.

Climate-based factors may be derived from Engineering Weather Data, chapter 3, NAVFAC P-89/AFM 88-29/TM 5-785. Sections 1-2 through 1-11 provide examples of sample calculations for climate-based factors for Springfield, Missouri. Figures SD-2 and SD-3 are reproduced from Engineering Weather Data, chapter 3, pages 3-20 and 3-21. Column designators are provided for simplified data location. The climate-based factors for any location in Engineering Weather Data can be derived in a similar fashion.

Before beginning the savings analysis at a particular location, those factors which are related to climate should be calculated. The derived values of the climate-based factors may be entered into the form shown in figure SD-1 for easy reference while performing the system analyses. The paragraph reference indicates the paragraph in this section where a method of determining the data is outlined. If actual weather data for the activity under study is available it should be used in preference to calculated data. For example, if an activity has a yearly schedule for turning on central cooling equipment on 20 May and turning it off on 20 September then that time period should be used for the weeks of summer (WKS).

Climate Based Factors

Symbol	Description	SD Paragraph	Value	Units
ACWT	Average Condenser Water Temperature	1-2	———	°F
AND	Annual Number of Days for Warmup	1-3	———	Days/Yr
AST*	Average Summer Temperature	1-4	———	°F
AWT*	Average Winter Temperature	1-5	———	°F
CFLH	Annual Equivalent Full-Load Hours for Cooling	1-6	———	Hr/Yr
HFLH	Annual Equivalent Full-Load Hours for Heating	1-7	———	Hr/Yr
HS	Hours of Temperature Limit Shutoff for Summer	1-8	———	Hr/Yr
HW	Hours of Temperature Limit Shutoff for Winter	1-8	———	Hr/Yr
OAH*	Average Outside Air Enthalpy	1-9	———	Btu/lb
PRT*	Percent Run Time for Low Temperature Limit	1-10	———	%
WKS*	Weeks of Summer	1-11	———	Wk/Yr
WKW*	Weeks of Winter	1-11	———	Wk/Yr

*Data not necessary if computer methods are used.

LOCATION: ____

Figure SD-1. Climate-Based Factors Form

Springfield, Missouri, Data

Tempera-ture Range	May Obsn Hour Cp 01 to 08	May 09 to 16	May 17 to 24	May Total Obsn	May MCWB	June Obsn Hour Cp 01 to 08	June 09 to 16	June 17 to 24	June Total Obsn	June MCWB	July Obsn Hour Cp 01 to 08	July 09 to 16	July 17 to 24	July Total Obsn	July MCWB
110/114												0		0	77
105/109												1	0	1	74
100/104							0	0	0	73		2	0	2	74
95/93							9	2	11	74	0	10	3	13	74
90/94		1	0	1	76		23	6	29	74	0	42	13	55	75
85/89		17	3	20	70	1	45	15	61	73	2	63	26	91	74
80/84	0	41	14	55	69	8	57	31	96	71	12	59	42	113	72
75/79	3	46	24	73	66	24	42	50	116	69	41	39	65	145	71
70/74	18	46	46	110	64	58	32	59	149	67	96	23	63	182	69
65/59	47	41	54	142	61	74	20	44	138	64	69	7	29	105	65
60/64	71	30	49	150	58	42	8	22	72	60	21	1	6	28	60
55/59	47	16	29	92	53	21	3	7	31	55	7		1	8	56
50/54	30	7	18	55	49	10	1	3	14	51	1			1	51
45/49	21	3	8	32	44	2		0	2	46					
40/44	8	1	1	10	40	0			0	43					
35/39	3	0	1	4	36										
30/34	1		0	1	32										
25/29															
20/24															
		144					64					31			

Tempera-ture Range	August Obsn Hour Cp 01 to 08	August 09 to 16	August 17 to 24	August Total Obsn	August MCWB	September Obsn Hour Cp 01 to 08	September 09 to 16	September 17 to 24	September Total Obsn	September MCWB	October Obsn Hour Cp 01 to 08	October 09 to 16	October 17 to 24	October Total Obsn	October MCWB
110/114															
105/109															
100/104		2	0	2	74		0		0	70					
95/93		15	4	19	74		5	0	5	70					
90/94	0	40	10	50	74		14	3	17	70		1		1	66
85/89	1	64	25	90	72	0	33	9	42	70		7	0	7	67
80/84	7	56	42	105	71	2	42	16	60	68		24	3	27	66
75/79	31	39	63	133	70	6	46	32	84	66	0	32	8	40	63
70/74	92	21	59	172	68	32	45	53	130	65	4	41	19	64	61
65/59	67	8	30	105	64	64	30	55	149	62	18	36	39	93	60
60/64	35	2	11	48	60	54	16	35	105	58	39	35	48	122	56
55/59	10	0	3	13	55	38	6	22	66	53	45	31	39	115	52
50/54	4		0	4	51	27	2	12	41	49	43	22	37	102	48
45/49	1			1	47	13	0	3	16	45	36	11	28	75	43
40/44						3		0	3	41	32	5	18	55	39
35/39						0			0	38	17	2	6	25	35
30/34											10	1	3	14	30
25/29											2		0	2	25
20/24											0			0	22
		31					99								

Figure SD-2. Sample Weather Data - Cooling Season

Springfield, Missouri, Data

1	2	November					December					January					February					March					April					Annual Total			6	7
		Obsn Hour Cp					Obsn Hour Cp					Obsn Hour Cp					Obsn Hour Cp					Obsn Hour Cp					Obsn Hour Cp					Obsn Hour Cp				
																																3	4	5		
Temperature Range	Mean °F in Range	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB	01 to 08	09 to 16	17 to 24	Total Obsn	MCWB
110/114	112																																0		0	77
105/109	107																																1	0	1	74
			40					5					8					9					35					107								
100/104	102																																4	0	4	74
95/99	97																															0	39	9	48	74
90/94	92																											0		0	72	0	121	32	153	74
85/89	87																						0		0	58		3	0	3	66	4	232	78	314	72
80/84	82		0		0	63												0		0	63		2	0	2	63		14	3	17	65	29	295	151	475	70
75/79	77		4		4	64		0		0	63		0		0	64		1	0	1	59		5	1	6	61	0	25	9	34	63	105	279	252	636	68
70/74	72	0	14	1	15	61		1	0	1	56		2	0	2	59		3	1	4	58	0	11	3	14	58	4	33	21	58	61	304	272	325	901	66
65/69	67	4	22	7	33	58	0	4	0	4	55	1	6	1	8	56	0	5	2	7	55	3	17	9	29	56	15	32	3	77	58	362	228	300	890	62
60/64	62	7	24	15	46	55	2	11	3	16	53	3	10	4	17	55	2	12	5	19	52	6	22	17	45	52	33	33	34	100	55	315	204	249	768	57
55/59	57	13	25	21	59	50	3	16	7	26	50	4	14	8	26	51	3	18	9	30	49	10	25	19	54	49	34	27	38	99	51	235	181	203	619	52
50/54	52	20	33	31	84	46	9	23	15	47	46	7	16	11	34	46	8	26	19	53	46	17	27	29	73	45	32	25	33	90	46	208	182	208	598	47
45/49	47	30	32	39	101	42	14	33	23	70	42	9	25	17	51	42	18	30	28	76	42	24	33	36	93	41	38	24	29	91	42	206	191	211	608	42
40/44	42	41	32	33	106	38	24	34	34	92	38	17	26	29	72	37	25	29	34	88	38	37	31	39	107	38	32	15	23	70	38	219	173	211	603	38
35/39	37	34	21	34	89	34	33	33	43	109	34	26	32	36	94	34	38	31	37	106	34	56	33	39	128	34	28	8	15	51	35	235	160	211	606	34
30/34	32	32	14	27	73	30	50	41	47	138	30	45	39	42	126	30	45	29	38	112	30	37	23	29	89	30	17	2	5	24	30	237	149	191	577	30
25/29	27	30	10	17	57	25	42	23	32	97	25	46	30	36	112	25	35	18	23	76	25	34	11	17	62	26	6	0	0	6	26	195	92	125	412	25
20/24	22	16	5	8	29	21	31	13	22	66	21	28	21	28	77	21	20	11	15	46	20	12	4	6	22	21	0		0	0	21	107	54	79	240	21
15/19	17	8	2	5	15	16	19	6	9	34	16	22	11	14	47	16	15	7	8	30	16	10	2	3	15	16	0			0	19	74	28	39	141	16
10/14	12	4	1	1	6	11	10	6	6	22	11	20	8	10	38	11	10	2	3	15	11	2	1	1	4	11						46	18	21	85	11
5/9	7	1	0	0	1	6	6	2	5	13	6	8	5	5	18	6	3	1	1	5	6	1	0	1	2	6						19	8	12	39	6
0/4	2						4	1	1	6	2	6	2	3	11	1	2	1	0	3	1	1			1	2						13	4	4	21	2
.5/.1	-3						1			1	.3	3	1	1	5	.4	0	0	0	0	.4											4	1	1	6	.4
.10/.6	-8											1	0	0	1	.7	0		0	0	.8											1	0	0	1	.7
COLUMN DESIGNATOR Col 1	Col 2																															Col 3	Col 4	Col 5	Col 6	Col 7

Figure SD-3. Sample Weather Data - Heating Season

SD 1-2. AVERAGE CONDENSER INLET WATER TEMPERATURE (ACWT)

The purpose of this procedure is to find the average condenser inlet water temperature obtainable from a cooling tower during the cooling season. This value can then be used in the condenser water temperature reset savings calculations for any cooling tower in the same geographic area.

Using the Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.) compile a data table similar to the one below. The example has been calculated using information from figure SD-3, columns 1, 4, and 7. Under column A, list the mean coincident wet bulb temperature (MCWB, column 7, figure SD-3) for temperature ranges above 55° F (column 1, figure SD-3) (as shown below). Assume an approach temperature (the difference in temperature between the outside air wet bulb temperature and condenser inlet water temperature) of 10°F and add this (i.e. 10°F) to each individual mean coincident wet bulb temperature (column A) and list in column B.

If the facility operates only during normal operating hours list the annual hours of occurrence (column 4, figure SD-3) for the 0900 to 1600 hour period (as in column C) and total the column. Calculate the temperature hours, column D, by multiplying individual condenser water temperatures (column B) by the corresponding hours of occurrence (column C) and total the column. The average condenser inlet water temperature is computed by dividing the total of the temperature hour column (D) by the total of the 0900 to 1600 hours of occurrence column (C).

A. Mean Coincident Wet Bulb °F	B. Condenser Water Temp. (A + 10°)	C. 0900 to 1600 Hours of Occurrence	D. Temperature Hours (B x C)
77	87	0	0
74	84	1	84
74	84	4	336
74	84	39	3,276
74	84	121	10,164
72	82	232	19,024
70	80	295	23,600
68	78	279	21,762
66	76	272	20,672
62	72	228	16,416
57	67	204	13,668
52	62	131	11,222
Totals		1,856	140,224

The average condenser inlet water temperature is calculated as follows:

ACWT = Total of D/Total of C
= 140,224/1,856
= 75.6°F

SD 1-3. ANNUAL NUMBER OF DAYS REQUIRING MORNING WARMUP (AND)

The purpose of this procedure is to calculate the annual number of days requiring morning warmup (AND). Results of this procedure will be used in savings calculations for Ventilation and Recirculation and Optimum Start/Stop. Using the Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.) compile a data table similar to the one below. The example has been calculated using information from figure SD-3 columns 1 and 3. Assuming the startup time is early morning, list (columns E and F) the temperature ranges below 60°F (column 1, figure SD-3) and the corresponding hours of occurrence for 0100 to 0800 hours (column 3, figure SD-3). Total column F and divide by 8 to get the annual number of days that warmup is required (AND).

E. Temperature Range °F	F. 0100 to 0800 Hours of Occurrence
55/59	235
50/54	208
45/49	206
40/44	219
35/39	235
30/34	237
25/29	195
20/24	107
15/19	74
10/14	46
5/9	19
0/4	13
-5/-1	4
-10/-6	1
-11 & below	0
Total	1,799

The annual number of days that warmup is required is calculated as follows:

$$\text{AND} = (\text{Total of F})/8$$
$$= 225$$

SD 1-4. AVERAGE SUMMER TEMPERATURE (AST)

The purpose of this procedure is to calculate the average summer temperature (AST). The results of this procedure will be used in the savings calculations for Scheduled Start/Stop. Using the Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.), compile a data table similar to the one below. The example has been calculated using information from figure SD-3 columns 2, 3, and 5. List in column H, F and I respectively, mean temperature in range values above 75°F (column 2, figure SD-3) and the corresponding annual total hours of occurrence for time periods 0100 to 0800 hours and 1700 to 2400 hours (columns 3 and 5, figure SD-3). For each line entry develop column J by adding the values in columns F and I and multiplying by the value in column H (i.e., column J = line entry for column F + I x column H). Total columns F, I, and J. Add totals of F and I. Divide the total of column J by sum of column F and I totals to get Average Summer Temperature (AST).

H. Mean °F in Range	F. 0100 to 0800 Hours of Occurrence	I. 1700 to 2400 Hours of Occurrence	J. Annual Summer Degree Hours (F + I) x H
112	0	0	0
107	0	0	0
102	0	0	0
97	0	9	873
92	0	32	2,944
87	4	78	7,134
82	29	151	14,760
77	105	252	27,489
Totals	138 hr	522 hr	53,200 °F-hr/yr

The average summer temperature is calculated as follows:

AST = Total of J/(Total of F + Total of I)
= 53,200/(138 + 522)
= 80.6°F

SD 1-5. AVERAGE WINTER TEMPERATURE (AWT)

The purpose of this procedure is to calculate the average winter temperature. The results of this procedure will be used in the savings calculations for Scheduled Start/Stop and Ventilation/Recirculation. Using the Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.), compile a data table similar to the one below. The example has been calculated using information from figure SD-3 columns 2 and 6. Under column H list the mean ^{O}F in range for temperatures below $65^{O}F$ (column 2, figure SD-3). Under column K list the corresponding annual total hours (column 6, figure SD-3) for the individual mean ^{O}F temperature. Total column K. Calculate the annual winter degree hours (column L) by multiplying the mean ^{O}F in range value (column H) by the corresponding annual total hours value (column K). Total column L. Calculate the average winter temperature (AWT) by dividing the total of column L by the total of column K.

H. Mean ^{O}F in Range	K. Annual Total Hours	L. Annual Winter Degree Hours H x K
62	768	47,616
57	619	35,283
52	598	31,096
47	608	28,576
42	603	25,326
37	606	22,422
32	577	18,464
27	412	11,124
22	240	5,280
17	141	2,397
12	85	1,020
7	39	273
2	21	42
-3	6	-18
-8	1	-8
Totals	5,324 hr/yr	228,893 ^{O}F-hr/yr

The average winter temperature is calculated as follows:

$$
\begin{aligned}
AWT &= \text{Total of L/Total of K} \\
&= 228,893/5,324 \\
&= 43.0^{O}F
\end{aligned}
$$

SD 1-6. ANNUAL EQUIVALENT FULL-LOAD HOURS FOR COOLING (CFLH)

The purpose of this procedure is to calculate the annual equivalent full-load hours for cooling (CFLH). The results of this procedure will be used in savings calculations for Chiller Water Temperature Reset and Condenser Water Temperature Reset. A value can also be chosen from the 1980 Systems ASHRAE Handbook. Using Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.), compile a data table similar to the one below. Under column H list the mean °F in range above and or equal to 65°F (column 2, figure SD-3). For daytime operation list under column C the corresponding 0900 to 1600 hours of occurrence (column 4, figure SD-3) for each mean °F temperature (for 24-hour operation use the annual total hours of occurrence data instead, column 6, figure SD-3). Calculate degree hours by subtracting 65°F from individual mean °F in range values (column H) and multiplying by the corresponding hours of occurrence value (column C) and list under column M. Total column M. Obtain the 2.5% summer design data dry bulb temperature (i.e., cooling design temperature) for your location from chapter 1 of the Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5-785. For the example calculation (location: Springfield, Mo.) the value is 93°F. Determine the annual equivalent full-load hours for cooling (CFLH) by dividing the total of column M by the cooling design temperature - 65°F.

H. Mean °F In Range	C. 0900 to 1600 Hours of Occurrence	M. Degree Hours C x (H - 65°F)
112	0	0
107	1	42
102	4	148
97	39	1,248
92	121	3,267
87	232	5,104
82	295	5,015
77	279	3,348
72	272	1,904
67	228	456
Total		20,532°F-hr

The annual equivalent full-load hours for cooling is calculated as follows:

$$\text{CFLH} = \frac{\text{Total of M}}{\text{Cooling Design Temperature} - 65^{\circ}}$$

$$= 20{,}532/(93^{\circ}F - 65^{\circ}F)$$

$$= 733 \text{ hr/yr}$$

SD 1-7. ANNUAL EQUIVALENT FULL-LOAD HOURS FOR HEATING (HFLH)

Results of this procedure will be used in savings calculations for Hot Water Outside Air Reset. The purpose of this procedure is to calculate the annual equivalent full-load hours for heating (HFLH). The results of this procedure will be used in savings calculations for Hot Water Outside Air Reset. Using Engineering Weather Data for your area (figure SD-3 for Springfield, Mo.), compile a data table similar to the one below. The example has been calculated using information from figure SD-3, columns 2, 4, and 6. Under column H list the mean °F in range values below 65°F (column 2, SD-3). For daytime operation, list under column C the corresponding 0900 to 1600 hours of occurrence value (column 4, figure SD-3) for each mean °F temperature value. (For 24-hour operation use the annual total hours of occurrence data instead, column 6, figure SD-3.) Calculate degree hours by subtracting 65°F from individual mean °F in range (column H) values and multiplying by the corresponding hours of occurrence (column C) value and list under column N. Total column N. Obtain the 97.5% heating design data dry bulb temperature (i.e., heating design temperature) from chapter 1 of the Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5785. For the example calculation (location: Springfield, Mo.) the value is 9°F. Determine the annual equivalent full-load hours for heating (HFLH) by subtracting the heating design temperature value from 65°F and dividing that value into the total of column N.

H. Mean °F In Range	C. 0900 to 1600 Hours of Occurrence	N. Degree Hours C x (65°F - H)
62	204	612
57	181	1,448
52	182	2,366
47	191	3,438
42	173	3,979
37	160	4,480
32	149	4,917
27	92	3,496
22	54	2,322
17	28	1,344
12	18	954
7	8	464
2	4	252
-3	1	68
-8	0	0
Total		30,140°F-hr

The annual equivalent full-load hours for heating is calculated as follows:

$$\text{HFLH} = \frac{\text{Total of N}}{65^\circ - \text{Heating Design Temperature}}$$

$$= 30{,}140/(65^\circ - 9^\circ) = 538 \text{ hr/yr}$$

SD 1-8. HOURS FOR OUTSIDE AIR TEMPERATURE SHUTOFF (HS AND HW)

The purpose of this procedure is to calculate the hours for outside air temperature shutoff for both summer and winter. The results of this procedure will be used in savings calculations for Outside Air Shutoff Limit. Using the Engineering Weather Data for your area (figure SD-2 and SD-3 for Springfield, Mo.), calculate the hours in summer (HS) during which the outside temperature is below summer thermostat set limit (78°F) and the hours in winter (HW) during which the outside temperature is above winter thermostat set limit (65°F) for your activity. For heating savings (HS) consider the months during which the heating auxiliaries such as hot water pumps are scheduled to operate at the facility under study (if schedule is poorly defined use weeks of winter from SD 1-11). From weather data sum up the total number of hours during the heating season that the temperature is above 65°F. In a similar fashion, determine the number of hours below the cooling season temperature limit of 78°F.

The example has been calculated using information from figures SD-2 and SD-3. The example assumes the heating season to be November through April and the cooling season to be from mid-May through September. Only the 0900 to 1600 hours time period (normal office hours) is considered.

Hours in winter when outside temperature is above

winter limit (65°F):

$$HW = \underbrace{(22 + 14 + 4)}_{\text{Nov}} + \underbrace{(4 + 1)}_{\text{Dec}} + \underbrace{(6 + 2)}_{\text{Jan}} + \underbrace{(5 + 3 + 1)}_{\text{Feb}} + \underbrace{(2 + 5 + 11 + 17)}_{\text{March}}$$

$$+ \underbrace{(3 + 14 + 25 + 33 + 32)}_{\text{April}}$$

$$= (40) + (5) + (8) + (9) + (35) + (107)$$

$$= 204 \text{ hr/yr}$$

Hours in summer when outside temperature is below

summer set limit (78°F):

$$HS = \underbrace{0.5(46 + 41 + 30 + 16 + 7 + 3 + 1)}_{\text{0.5 May}} + \underbrace{(32 + 20 + 8 + 3 + 1)}_{\text{June}} + \underbrace{(23 + 7 + 1)}_{\text{July}}$$

$$+ \underbrace{(21 + 8 + 2)}_{\text{August}} + \underbrace{(45 + 30 + 16 + 6 + 2)}_{\text{September}}$$

$$= 0.5(144) + 64 + 31 + 31 + 99$$

$$= 273 \text{ hr/yr}$$

SD 1-9. AVERAGE OUTSIDE AIR ENTHALPY (OAH)

The purpose of this procedure is to calculate the average outside air enthalpy (OAH). The results of this procedure will be used in the savings calculations for Scheduled Start/Stop. Using Engineering Weather Data for your area, compile a data table similar to the one below. The example has been calculated using information from figure SD-3 columns 3, 5 and 7. List in columns A, F, and I respectively the mean coincident wet bulb temperature (MCWB) (column 7, figure SD-3) above or equal to 68°F and the corresponding annual total hours of occurrence for the 0100 to 0800 and 1700 to 2400 (columns 3 and 5 figure SD-3) time periods. Total columns F and I. Calculate the degree hours for each mean coincident wet bulb temperature by adding the corresponding column F and I hours of occurrence values together and multiplying by corresponding mean coincident wet bulb temperature (column A); list these values under column O. Total column O. Calculate the average wet bulb temperature by dividing the column O total by the sum of column F plus column I totals.

A. Mean Coincident Wet Bulb °F	F. 0100 to 0800 Hours of Occurrence	I. 1700 to 2400 Hours of Occurrence	O. Degree Hours A x (F + I)
77	0	0	0
74	0	0	0
74	0	0	0
74	0	9	666
74	0	32	2,368
72	4	78	5,904
70	29	151	12,600
68	105	252	24,276
Total	138 hr	522 hr	45,814 hr-°F

The average wet bulb temperature is calculated as follows:

Average wet bulb temperature = Total of O/(Total of F + Total of I)

= 45,814/(138 + 522)

= 69.4°F

The outside air enthalpy (OAH) can then be obtained by consulting Standardized EMCS Energy Savings Calculations, CR 82.030, appendix A.2. In this example, the OAH which corresponds to 69.4°F - WB is 33.34 Btu/lb.

SD 1-10. PERCENT RUN TIME FOR LOW TEMPERATURE LIMIT (PRT)

The percent run time (PRT) is the percentage of scheduled off time during unoccupied periods when the fans and pumps must come back on in order to maintain a 55°F set-back temperature. The determined value will be used in Scheduled Start/Stop savings calculations. Find the annual heating degree days for the location under study in chapter 1 of Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5-785. The corresponding PRT can be found in figure SD-4. For this Springfield, Mo. example, the number of heating degree days is 4,570, and the corresponding PRT is 15.

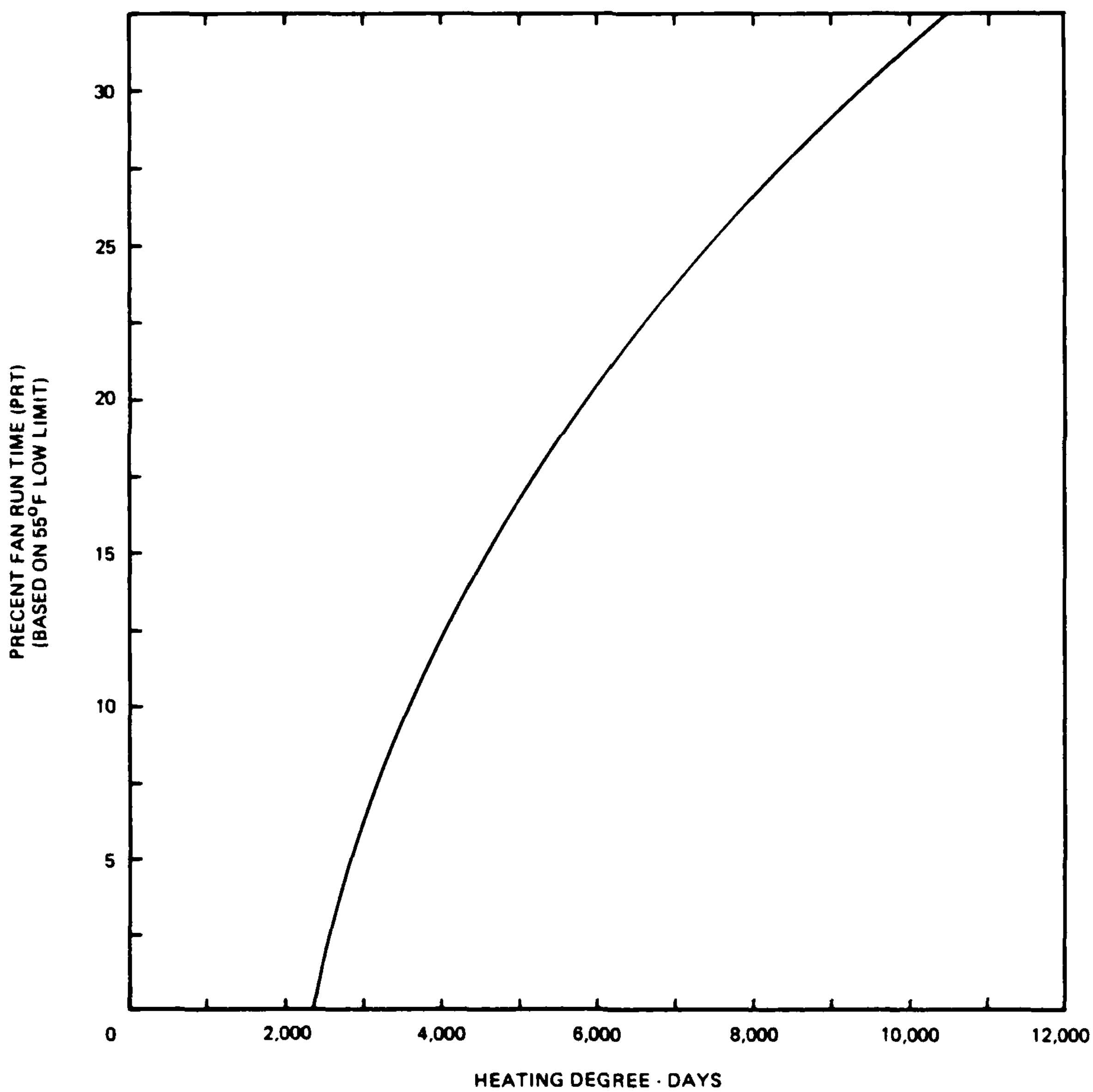


Figure SD-4. Heating Degree Days

SD 1-11. WEEKS OF SUMMER (WKS) AND WEEKS OF WINTER (WKW)

The purpose of this procedure is to calculate the weeks of winter (WKW) and weeks of summer (WKS). The results of this procedure will be used in the savings calculations for Scheduled Start/Stop, Ventilation/Recirculation, Day/Night Setback, Reheat Coil Reset, and Hot Deck/Cold Deck Temperature Reset. Using Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5-785, for your area, compile a data table similar to the one below. Under columns E and K respectively list the temperature range (column 1, figure SD-3) below 55°F and the corresponding total hours observed (total obsn) (column 6, figure SD-3). Total column K. Weeks of winter (WKW) and weeks of summer (WKS) are calculated using the equations shown below:

E. Temperature Range °F	K. Annual Total Hours
50/54	598
45/49	608
40/44	603
35/39	606
30/34	577
25/29	412
20/24	240
15/19	141
10/14	85
5/9	39
0/4	21
-5/-1	6
-10/-6	1
Total	3,937 hr/yr below 55°F

The weeks of winter are calculated as follows:

$$WKW = \frac{(\text{Total of K})\ \text{hr/yr}}{(24\ \text{hr/day})\ (7\ \text{day/wk})}$$

$$= 3{,}937/(24)(7)$$

$$= 23.4\ \text{wk/yr}$$

The weeks of summer are calculated as follows:

$$WKS = 52\ \text{wk/yr} - WKW$$

$$= 52 - 23.4$$

$$= 28.6\ \text{wk/yr}$$

SD 2. BUILDING-SPECIFIC FACTORS

SD 2-1. INTRODUCTION

Prior to performing ECO procedure calculations certain building specific factors should be determined. These factors may be entered in forms like the one shown in figure SD-5 for easy reference. A discussion of these factors and their derivations follows in paragraphs SD 2-2 through SD 2-4. It is important when deriving thermal parameters of a building to take into account any proposed architectural modifications.

SD 2-2. BUILDING THERMAL TRANSMISSION FACTOR (BTT)

This factor is used in various HVAC ECO calculations.

$$BTT = ((Uo \times AW) + (I \times 1.08\ \text{Btu/cfm-}^{o}\text{F-hr}))/AF$$

where:

*Uo = Combined U Factor for All Exterior Surfaces (walls, windows, doors, roof) in Btu/hr-^{o}F-ft^2 (see tables section, table 1)

AW = Total Area of Exterior Surfaces in ft^2

*I = Total Infiltration for Building in cfm

AF = Total Floor Area of the Building in ft^2

*The values for these factors may be calculated by methods discussed in ASHRAE Handbook, 1981 Fundamentals, chapters 22 and 23 or see ECO BE 8 for infiltration values.

SD 2-3. ANNUAL EQUIPMENT RUN TIME FOR MORNING WARMUP (ERT)

The equipment run time (ERT) is the number of hours per year that a system must run in the mornings before occupancy to bring the temperature up to comfort conditions. The calculated value will be used in savings calculations for Optimum Start/Stop. Calculate the combined wall Uo factor by standard methods such as described in paragraph SD 2-2 or in the ASHRAE Handbook 1981 Fundamentals, chapter 23. Find the annual heating degree days (HDD) for the location under study in map 1 or chapter 1 of Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5-785. The corresponding ERT can be found in figure SD-6 or SD-7. For a brick building with an overall U-factor of 0.21 in Springfield, Missouri (HDD of 4,570), the corresponding ERT from figure SD-7 is 290 hours per year.

BUILDING: ______________________

BTT = Building Thermal Transmission*

= [(U-factor x exterior area) + (Infiltration x 1.08)]/Total Floor Area

= [(________ Btu/hr-^{o}F-ft^{2} x ________ ft^{2}) + (______ cfm x 1.08 Btu/cfm-^{o}F-hr)]/

______ ft^{2}

= ________ Btu/hr-^{o}F-ft^{2}

ERT = Annual Run Time of Equipment for Morning Warmup*

Heating Degree Days = ______________ ^{o}F-days

Combined U-factor (Uo) = ______________ Btu/hr-^{o}F-ft^{2}

From figure SD-6 or SD-7: ERT = __________________ hr/yr

Cooling Equipment

System No.	System Type	Systems Served	CPT*

Heating Equipment

System No.	System Type	Systems Served	HEFF*	HV*

*See SD 2-2, 2-3

Figure SD-5. Building-Specific Factors

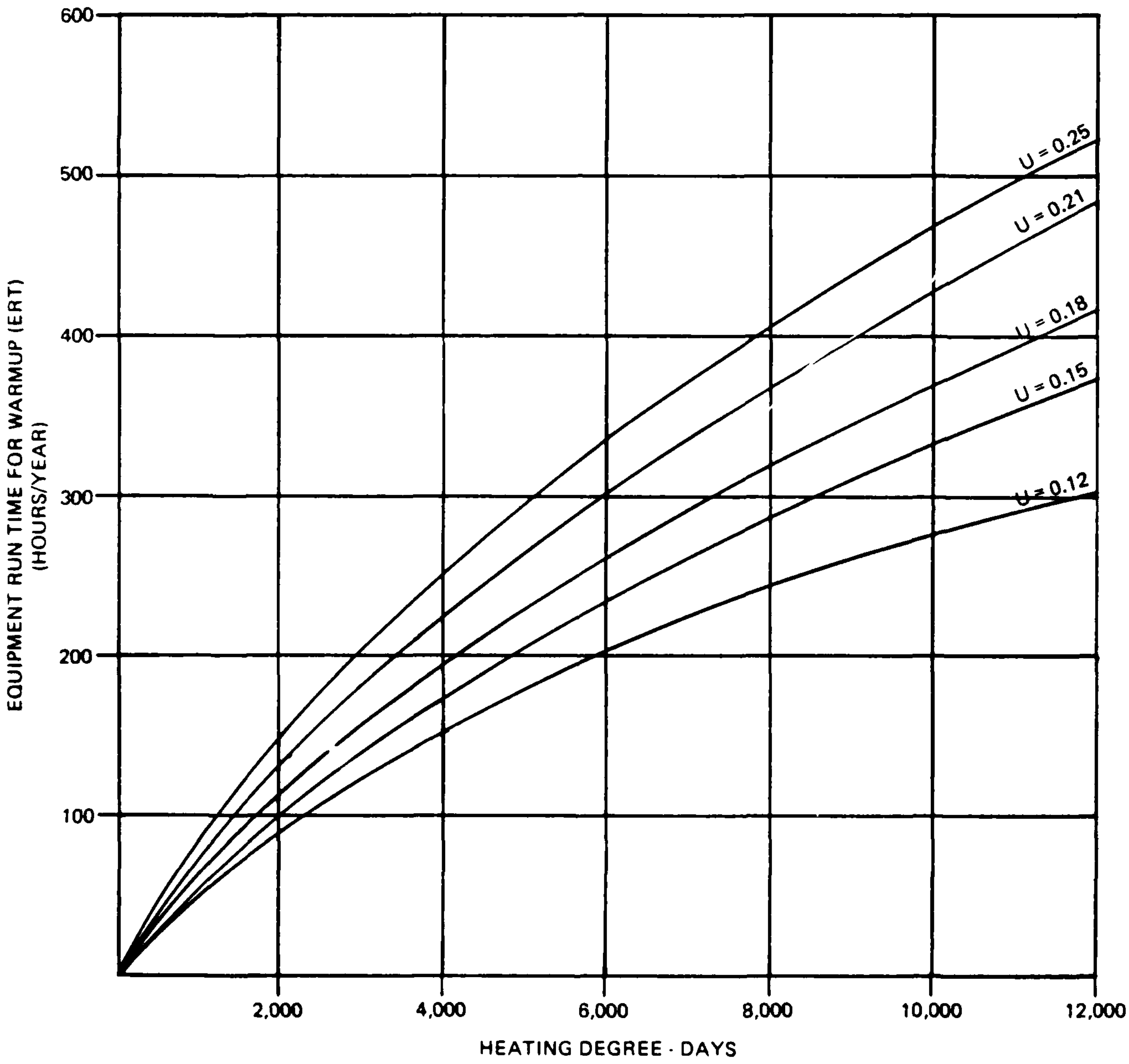


Figure SD-6. Light Construction

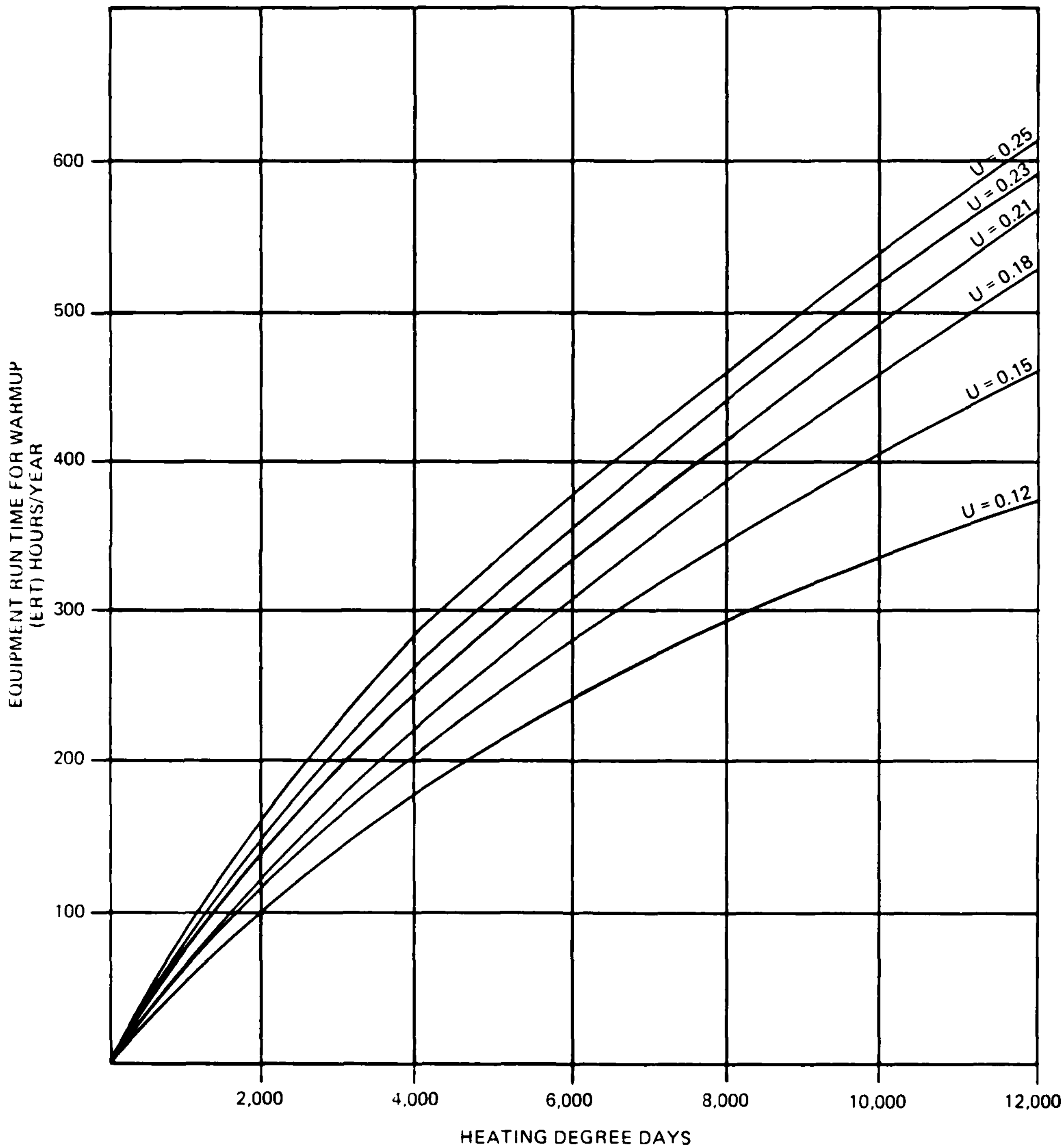


Figure SD-7. Heavy Construction

SD 2-4. MISCELLANEOUS FACTORS

CPT = rate of energy consumption per ton of refrigeration in kw/ton or lb (steam)/ton-hr.

This figure will be the same for all air handling systems using chilled water from the same central chiller. DX units or package units will be exceptions. Use a value derived from manufacturer's catalog or nameplate data for the particular model if available; or use the approximate power inputs for compressors listed in the ASHRAE Handbook, 1980 Systems, table 2, p. 43.10.

For steam-driven refrigeration machines use:

steam absorption machine - 18 lb/ton-hr
steam turbine-driven machine - 40 lb/ton-hr

EER = Cooling Energy Efficiency Ratio (cooling capacity/input watts). A term used by industry to define refrigeration efficiency. This is a site-specific factor that may be obtained from nameplate data or manufacturer. If actual EER is unobtainable use 6.8 for average value.

HEFF = heating efficiency of the system.

When calculating heating savings for boilers and domestic hot water heaters, use manufacturer's data on efficiencies if available. Typically, the seasonal efficiency of an oil- or gas-fired boiler and hot water heating system is between 0.60 and 0.70, respectively. The seasonal efficiency of a coal-fired boiler is somewhat lower, 0.40 - 0.50. For separate domestic hot water heaters, seasonal efficiencies are about 0.70 for oil-fired heaters, 0.75 for gas-fired heaters, and 0.95 for electric water heaters.

When calculating heating savings for converters, heat exchanger effectiveness must be included. Use a factor of 0.90 combined with the efficiency of the boiler which serves the converter if actual equipment data is not available. For example, if a boiler with an efficiency of 0.65 supplies steam to a steam/hot water converter, then the total heating efficiency (HEFF) of the converter will be 0.65 times 0.90 or 0.585.

When calculating heating savings for secondary systems, the distribution losses also must be taken into account. The distribution efficiencies of hot water systems may be estimated based on the flow rate and the temperature difference between the outlet of the boiler or converter and the inlet to the air handler heating coil. If this data is not available, assume a distribution efficiency of 0.90. This must be multiplied by the boiler or converter efficiency to determine the combined heating efficiency (HEFF) of the secondary system.

For electrical resistance duct heaters assume a heating efficiency of 1.0.

HV = heating value (Btu/gal, Btu/kwh) of fuel.

L = load factor

This takes into account the efficiency and partial load of motors. For conservation savings estimation, use 0.8 based on:

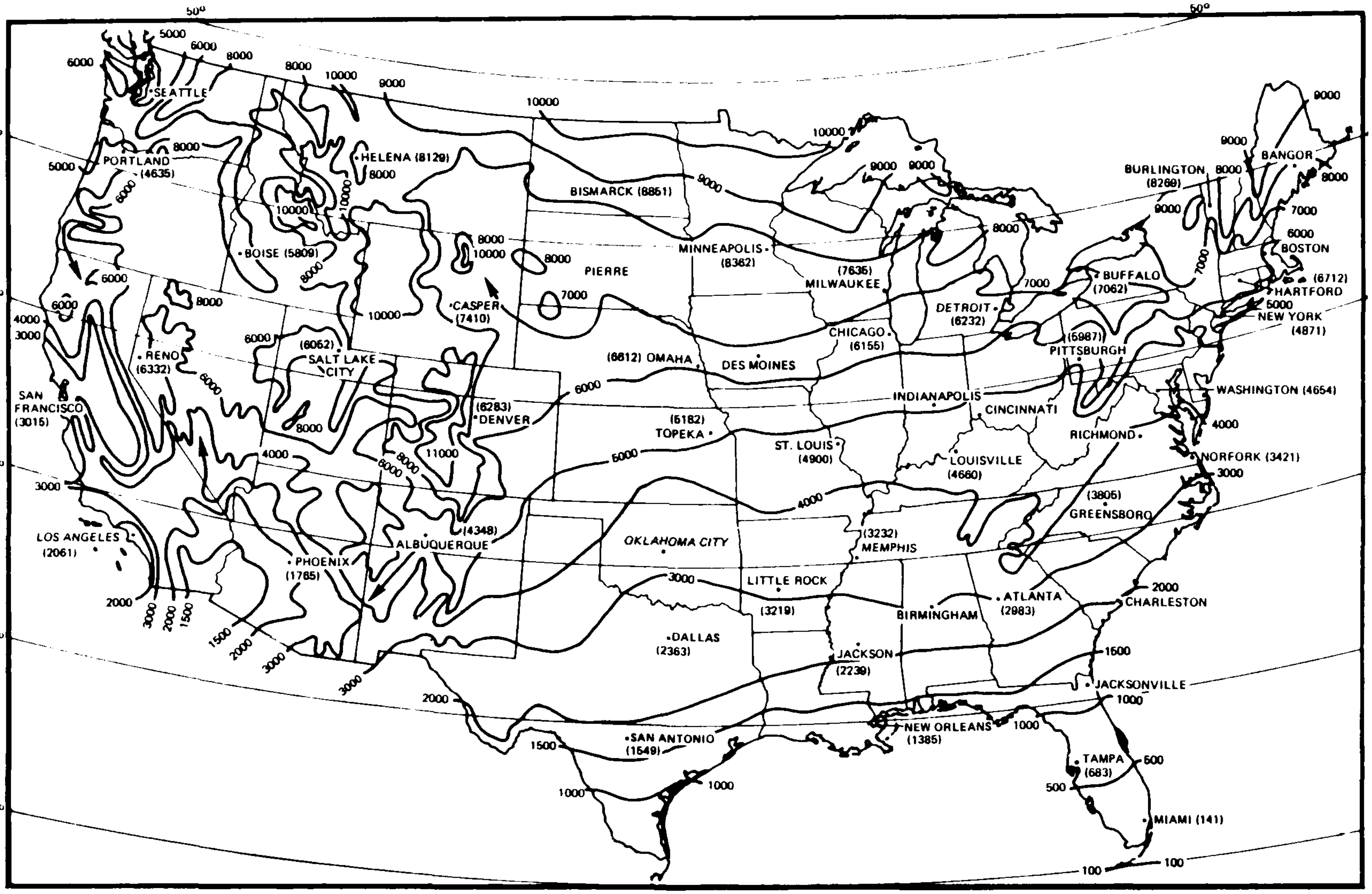
$$L = \frac{\text{Partial Load}}{\text{Efficiency at Partial Load}} = \frac{0.68}{0.85} = 0.8$$

Other values should be used if information on a particular motor indicates such.

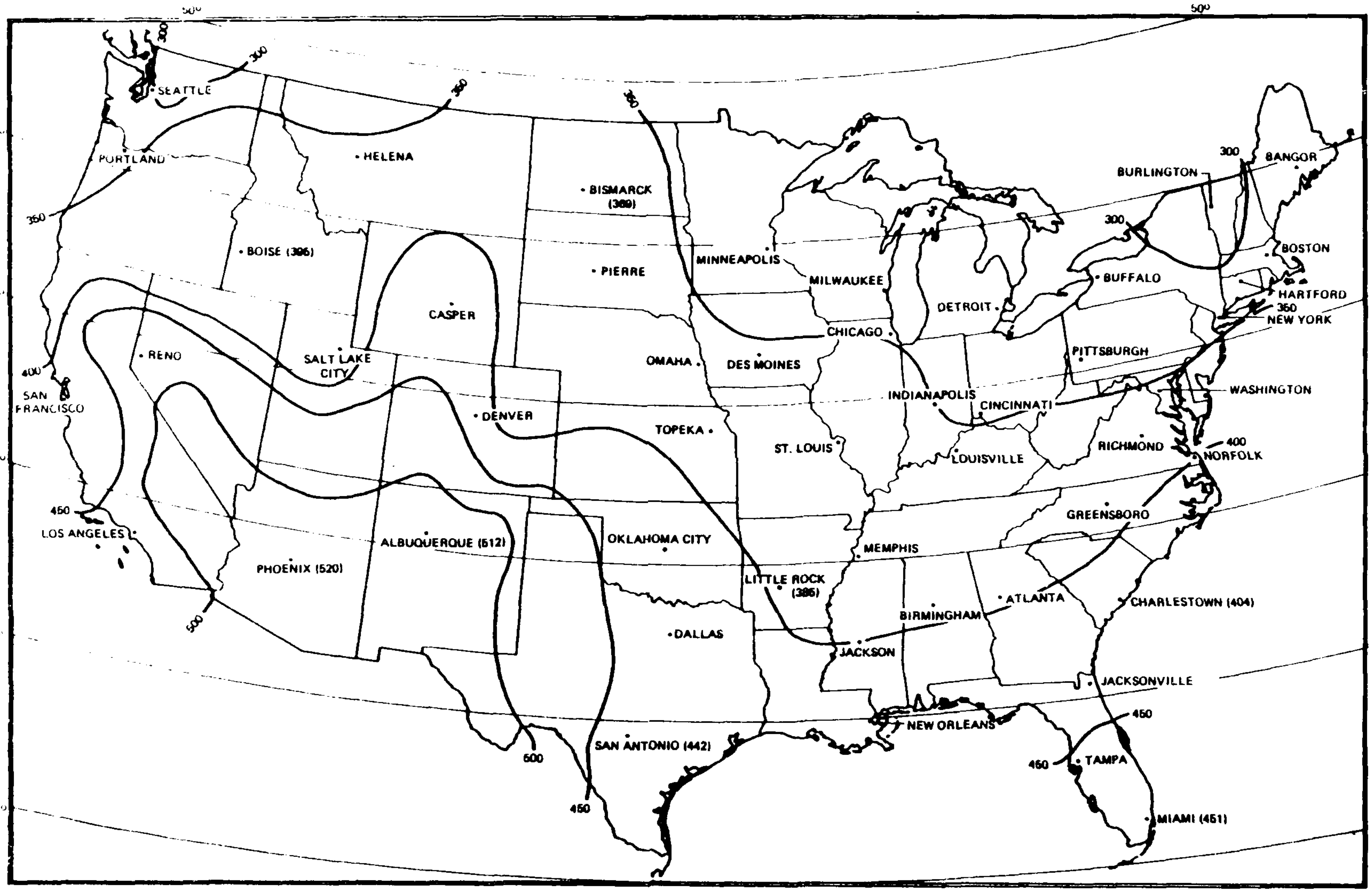
LTL = low temperature limit in ^{o}F for shutdown periods, usually is $50^{o}F$ or $55^{o}F$.

SSP = summer thermostat setpoint in ^{o}F; $78^{o}F$ is recommended for normal occupancy.

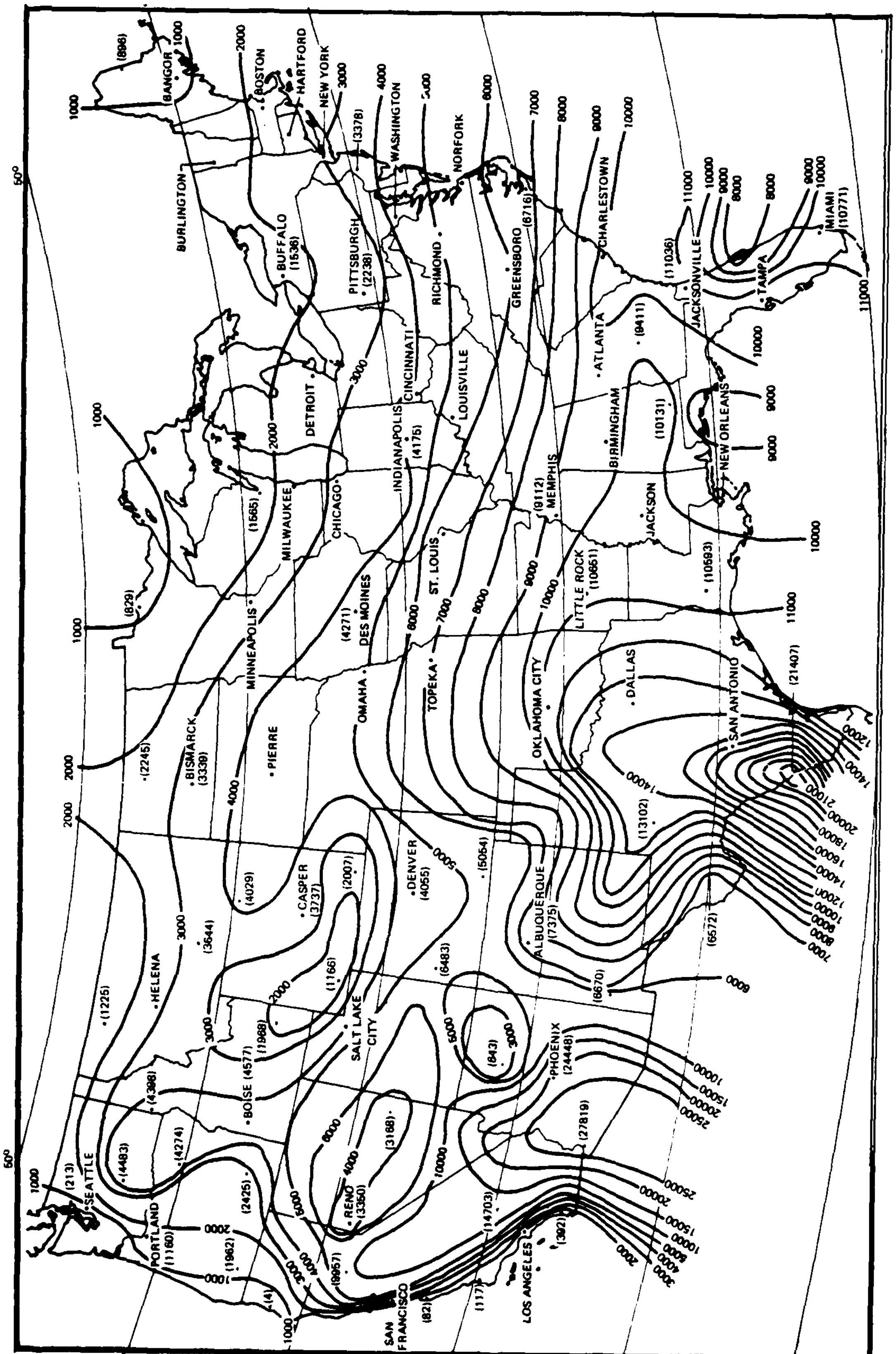
WSP = winter thermostat setpoint in ^{o}F; $65^{o}F$ is recommended for normal occupancy.



Map 1. Annual Heating Degree Days (°F Days) (Base 65°F)



Map 2. Annual Mean Daily Solar Radiation in Langleys



Map 3. Annual Dry Bulb Degree Hours Above 78°F

Table SD1. Energy Conversion Units

The common unit of energy measure is the British thermal unit (Btu) which is the unit used in this handbook to calculate and compare energy costs and savings. To convert from one common energy unit to another, refer to this table.

To Convert	Into	Multiply By
Barrels, oil	Gallons	42.0
Cubic feet, natural gas	Therms	0.01
Cubic feet, natural gas	Btu	1,000
Gallons, No. 2 oil	Btu	139,600*
Gallons, No. 4 oil	Btu	145,100*
Gallons, No. 5 oil	Btu	148,800*
Gallons, No. 6 oil	Btu	152,400*
Gallons, kerosene	Btu	135,000*
Gallons, gasoline	Btu	125,000*
Gallons, diesel oil	Btu	138,700*
Horsepower-hours	Btu	2,544
Horsepower-hours	Kwhs	0.7457
Horsepower	Btu/min	42.4176
Horsepower (boiler)	Btu/hr	33,479
Kilowatt-hours	Btu	3,413**
MCF natural gas	Btu	1,000,000
Short tons, eastern steam coal	Btu	23,100,000*
Short tons, western coal	Btu	21,000,000*
Short tons, anthracite coal	Btu	25,400,000*
Short tons, bituminous steam coal	Btu	21,600,000*
Short tons, lignite, brown coal	Btu	14,000,000*
Steam, saturated (lb)	Btu	1,000
Therms, natural gas	Cubic feet	100
Therms, natural gas	Btu	100,000
Tons, refrigeration	Btu/hr	12,000

* These are average values. Since exact Btu contact varies with type and source, contact supplier when extreme accuracy is essential.

** When it is necessary to account for generation and distribution line losses and total Btu of the fuel used to generate electricity, use 11,600.

Table SD2. Weather Data (Including EIH, EIC, ESF)

	Winter		Summer		Energy Index			
State/ City	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
ALABAMA								
Birmingham	41.9	16.6	80.6	32.9	23.396	72.502	16.007	1,295 - 1,650
Montgomery	43.5	14.1	81.1	35.3	18.654	84.679	14.359	1,380 - 1,755
Huntsville	40.3	18.8	80.5	30.9	28.121	67.713	14.648	---
Mobile	44.7	10.4	79.4	38.4	13.085	89.391	13.173	1,490 - 1,895
ARIZONA								
Tucson	46.2	12.4	83.5	40.1	14.597	61.276	20.137	1,180 - 1,500
Flagstaff	35.6	33.4	73.5	18.6	58.436	20.262	22.345	---
Phoenix	46.4	11.4	86.0	41.3	13.297	69.363	19.797	1,540 - 1,960
ARKANSAS								
Blytheville	39.5	20.4	80.5	29.7	31.395	70.961	13.128	---
Little Rock	41.7	18.1	81.6	31.3	27.706	71.929	14.288	1,125 - 1,435
Ft. Smith	40.5	18.0	81.0	30.5	26.730	72.314	13.662	---
CALIFORNIA								
Los Angeles	50.2	8.9	72.0	32.6	8.555	42.111	37.315	1,435 - 1,825
San Diego	50.5	7.0	70.9	29.8	6.615	40.858	38.346	1,775 - 2,260
Santa Barbara	49.6	23.9	69.7	12.2	23.747	16.386	51.450	1,415 - 1,800
Bishop	40.2	21.3	82.2	30.4	31.976	45.019	19.932	---
Barstow	42.6	20.6	83.7	32.3	28.255	49.157	21.236	---
San Francisco	48.2	18.4	71.1	22.2	19.673	23.164	39.345	925 - 1,175
Sacramento	46.1	19.4	79.9	28.4	22.942	41.610	25.558	1,140 - 1,450

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

	Winter		Summer		Energy Index			
State/ City	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
COLORADO								
Denver	35.2	29.4	77.9	22.6	52.073	27.052	19.493	1,065 - 1,355
Colorado Springs	35.4	30.4	76.9	21.6	53.516	26.491	20.100	700 - 890
Trinidad	36.2	27.7	78.5	25.4	47.566	34.007	20.410	---
Grand Junction	36.3	27.5	80.3	23.7	47.075	32.076	16.074	---
DELAWARE								
Dover	38.4	25.2	77.5	23.6	40.280	50.337	13.533	---
Wilmington	38.2	26.0	77.5	23.7	41.839	46.409	14.161	---
FLORIDA								
Pensacola	44.7	10.4	79.4	38.4	13.085	106.944	13.511	1,655 - 2,105
Miami	49.3	1.6	80.4	50.1	1.616	143.912	4.011	2,010 - 2,560
Jacksonville	45.6	8.6	80.4	41.6	10.403	102.703	12.370	1,735 - 2,210
Orlando	48.5	3.0	78.5	46.2	3.159	113.377	9.440	1,855 - 2,360
Tampa	47.0	4.0	78.5	46.0	4.536	111.000	9.479	1,890 - 2,405
GEORGIA								
Atlanta	41.1	19.8	78.7	30.0	28.761	62.733	16.727	1,265 - 1,610
Augusta	42.6	16.0	80.7	35.1	21.946	80.520	16.159	1,320 - 1,680
Macon	43.3	14.5	80.3	34.8	19.340	77.085	15.065	1,370 - 1,740
Valdosta	45.0	10.7	80.0	38.9	13.289	94.043	15.355	---
Savannah	44.0	12.0	80.0	38.0	15.552	92.996	15.870	1,465 - 1,870

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
IDAHO								
Boise	38.1	31.4	78.8	19.7	50.698	27.709	16.613	710 - 905
Pocatello	35.1	33.3	78.6	18.8	59.161	23.551	16.107	620 - 790
Lewiston	40.2	29.7	78.8	18.9	44.586	26.574	17.155	---
ILLINOIS								
Chicago	34.2	30.0	77.0	20.9	54.756	38.791	12.434	755 - 960
Champaign	33.3	27.3	77.9	23.6	51.155	38.770	12.849	865 - 1,100
Peoria	34.0	26.0	78.0	24.0	47.736	38.770	12.080	---
Rockford	32.0	29.0	77.0	21.0	56.376	36.867	12.672	---
INDIANA								
Fort Wayne	34.8	28.5	77.7	22.5	51.095	42.551	12.500	780 - 995
South Bend	34.2	29.1	77.1	21.4	53.113	38.559	12.396	755 - 965
Indianapolis	35.8	26.7	78.0	23.9	46.426	45.515	12.548	895 - 1,140
Terre Haute	36.8	26.2	78.7	24.8	44.142	50.516	12.849	---
IOWA	32.1	28.0	78.4	21.9	54.281	41.213	12.645	795 - 1,010
Mason City	29.8	31.1	76.7	19.7	64.153	43.252	12.750	---
Sioux City	31.2	28.9	79.0	22.2	57.430	40.447	12.283	730 - 930
Council Bluffs	32.1	27.2	78.5	23.0	52.730	42.081	13.229	795 - 1,010

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
KANSAS								
Dodge City	35.9	25.4	81.4	25.6	44.028	40.237	15.436	---
Goodland	34.3	29.1	81.0	23.6	52.956	34.644	16.585	700 - 890
Kansas City	36.5	23.6	80.5	25.7	40.144	51.300	13.197	925 - 1,175
Wichita	37.0	22.6	81.2	27.0	37.832	51.367	13.956	935 - 1,195
KENTUCKY								
Louisville	38.4	23.5	79.9	26.6	37.562	54.019	13.700	935 - 1,190
Covington	36.8	25.1	78.2	24.4	42.288	43.478	13.678	890 - 1,135
Hopkinsville	38.2	22.0	79.7	28.4	35.402	60.109	13.752	---
LOUISIANA								
New Orleans	46.4	9.4	79.8	39.6	10.964	111.480	11.137	1,705 - 2,170
Alexandria	43.7	13.3	81.0	37.2	17.452	95.036	12.600	---
Shreveport	42.6	15.2	81.8	35.2	20.848	84.524	14.034	1,375 - 1,750
Lake Charles	45.5	10.4	80.4	39.2	12.636	107.632	10.886	1,670 - 2,125
MAINE								
Portland	34.5	33.7	74.4	15.5	60.963	20.847	16.547	---
MASSACHUSETTS								
Boston	35.1	31.1	76.0	19.8	52.252	35.537	14.644	775 - 985
Springfield	34.6	30.5	76.3	20.1	55.010	31.320	14.268	---

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
MICHIGAN								
Lansing	34.0	30.4	76.0	19.5	55.814	30.728	13.921	695 - 885
Grand Rapids	34.4	30.5	75.0	19.0	55.339	28.563	13.700	715 - 915
Traverse City	33.0	32.8	75.3	17.0	61.992	25.498	14.573	---
Sault Ste Marie	30.2	37.0	73.4	12.8	75.524	16.702	15.238	---
Detroit	33.8	30.5	75.8	19.2	56.327	32.997	12.892	760 - 965
MINNESOTA								
Duluth	28.0	37.0	73.5	12.7	79.920	16.700	15.573	450 - 570
International Falls	25.5	36.8	73.8	14.1	84.456	18.041	15.290	---
Minneapolis	29.3	31.0	76.8	18.8	64.784	30.661	12.968	---
MISSISSIPPI								
Biloxi	45.2	10.1	79.8	37.6	12.435	111.068	13.063	---
Jackson	43.0	14.8	81.1	35.3	19.980	86.108	14.250	1,365 - 1,740
Columbus	41.6	16.9	81.2	33.8	24.093	80.746	13.697	---
MISSOURI								
Kansas City	36.5	23.6	80.5	25.7	40.144	49.828	13.197	925 - 1,175
Columbia	36.1	24.4	80.2	25.7	42.031	51.319	13.148	---
Springfield	36.7	23.4	79.6	26.9	39.551	55.280	13.441	920 - 1,170
St. Louis	36.1	24.2	79.6	26.3	41.687	52.665	12.934	920 - 1,170

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
MONTANA								
Billings	34.6	32.1	78.1	18.4	57.896	22.470	17.211	620 - 790
Glasgow	27.9	33.5	77.8	17.5	72.541	18.250	15.687	---
Helena	32.9	36.0	76.1	15.5	68.234	17.479	17.186	450 - 575
Great Falls	33.8	33.8	76.6	16.9	62.422	19.523	17.374	580 - 740
NEBRASKA								
Omaha	32.1	27.2	78.5	23.0	52.730	42.081	13.229	795 - 1,010
Grand Island	32.6	28.6	79.4	22.7	54.672	37.486	13.892	---
North Platt	32.4	29.7	79.1	22.0	57.095	32.114	15.035	---
NEVADA								
Las Vegas	43.7	15.6	86.8	35.4	20.470	60.567	20.457	1,300 - 1,655
Ely	33.4	35.0	77.7	20.2	65.394	24.441	17.751	---
Winnemucca	36.2	31.9	80.4	22.3	54.779	31.783	17.697	---
Reno	35.0	33.0	79.0	21.0	58.806	25.515	19.097	640 - 815
NEW HAMPSHIRE								
Manchester	32.0	32.0	75.0	19.0	62.208	28.344	14.644	---
NEW JERSEY								
Trenton	37.5	26.9	77.1	22.9	44.304	40.689	13.772	895 - 1,135

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter: Avg Db Winter Temp	Winter: Length in Weeks	Summer: Avg Db Summer Temp	Summer: Length in Weeks	Energy Index: 10^6 BTU* Outside Air Heating Load (EIH)	Energy Index: 10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
NEW MEXICO								
Albuquerque	39.7	23.9	80.4	27.3	36.524	37.576	18.378	935 - 1,195
Alamogordo	41.0	19.2	81.8	32.5	27.994	45.039	20.855	---
Clovis	38.7	23.1	79.9	29.4	36.549	39.173	20.644	---
NEW YORK								
Albany	33.8	30.5	76.4	19.5	56.327	31.521	13.846	710 - 905
Buffalo	34.5	31.1	75.0	18.8	56.260	32.916	13.376	715 - 915
Syracuse	34.0	30.2	76.1	19.4	55.447	30.910	14.218	735 - 935
New York City	38.0	27.5	76.0	20.0	44.550	40.689	14.825	895 - 1,135
NORTH CAROLINA								
Greensboro	40.1	21.6	79.0	28.1	32.543	55.027	15.967	1,010 - 1,285
Raleigh	41.0	20.0	79.0	30.0	29.160	66.635	15.879	1,065 - 1,355
Wilmington	43.6	15.2	78.5	33.6	20.028	88.00	14.161	---
NORTH DAKOTA								
Bismarck	27.4	33.5	77.8	18.3	73.445	23.351	14.795	550 - 700
Grand Forks	24.6	34.4	76.1	16.9	80.620	22.163	14.133	---
Minot	27.2	34.7	76.4	16.2	76.451	19.282	15.380	---
Fargo	27.2	35.0	77.0	17.0	77.112	24.251	14.100	570 - 725

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
OHIO								
Cleveland	34.0	29.4	76.5	21.0	53.978	34.066	12.640	700 - 980
Dayton	36.2	25.4	78.4	24.3	43.617	41.818	13.163	840 - 1,070
Columbus	37.8	25.5	77.6	23.8	41.585	41.818	13.170	835 - 1,065
Toledo	33.8	29.5	76.8	21.3	54.481	32.997	12.647	755 - 960
Cincinnati	36.8	25.1	78.2	24.4	42.288	48.502	13.678	890 - 1,135
OKLAHOMA								
Altus	39.5	19.5	83.2	31.2	30.011	59.470	15.151	---
Oklahoma City	38.9	20.0	81.2	29.5	31.428	57.904	14.921	1,030 - 1,310
Tulsa	39.0	20.2	81.7	29.7	31.633	64.398	14.702	1,060 - 1,350
Enid	37.9	21.6	81.9	28.4	35.109	59.745	14.662	---
OREGON								
Burns	35.7	36.3	76.5	17.3	63.314	--	--	---
Medford	41.9	30.9	78.7	21.2	43.550	27.150	20.122	715 - 910
Pendleton	40.1	29.9	78.1	20.0	45.047	25.596	20.122	---
Portland	44.0	30.8	73.5	15.8	39.917	18.097	25.334	725 - 925
Eugene	44.0	30.8	74.0	15.0	39.917	21.073	25.003	690 - 885
PENNSYLVANIA								
Pittsburgh	35.1	28.2	76.0	21.9	50.100	35.361	14.056	790 - 1,010
Scranton	35.2	29.7	76.2	20.1	52.444	32.081	14.072	735 - 935
Williamsport	36.4	38.9	77.2	21.0	49.315	34.234	13.788	---
Philadelphia	38.2	26.0	77.5	23.7	41.839	40.689	14.161	885 - 1,130

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
RHODE ISLAND								
Providence	37.6	28.8	74.7	18.7	47.278	34.426	15.203	770 - 985
SOUTH CAROLINA								
Charleston	43.3	14.2	78.7	36.0	18.940	90.941	15.437	1,400 - 1,785
Columbia	43.2	16.0	79.7	33.4	21.427	73.867	16.159	1,280 - 1,630
Myrtle Beach	43.0	15.9	77.9	32.3	21.465	83.593	15.704	---
SOUTH DAKOTA								
Rapid City	32.6	30.7	78.8	19.6	58.686	24.746	17.353	670 - 855
Huron	28.5	31.4	78.9	20.4	66.976		12.404	615 - 780
Sioux Falls	29.2	30.4	78.0	20.5	63.694	32.166	13.279	680 - 865
TENNESSEE								
Memphis	40.5	18.9	81.1	30.4	28.067	71.798	13.553	1,120 - 1,425
Nashville	39.3	23.3	79.7	28.4	36.110	62.170	13.100	1,055 - 1,345
Knoxville	39.5	21.5	80.0	29.0	33.089	56 695	14.727	1,030 - 1,310
TEXAS								
Amarillo	38.1	23.0	80.4	28.4	37.136	40.959	17.748	950 - 1,210
Lubbock	39.1	20.8	80.3	30.8	32.460	41.000	16.900	1,020 - 1,300
Dallas	42.5	15.1	82.8	34.6	20.793	74.244	15.239	1,360 - 1,730
San Antonio	46.0	8.9	82.7	41.3	10.573	88.888	14.457	1,520 - 1,935
Corpus Christi	48.1	4.8	80.3	43.0	5.158	128.001	9.795	1,820 - 2,320
Houston	47.0	6.0	80.3	42.0	6.804	111.808	10.700	2,065 - 2,630

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
UTAH								
Salt Lake City	36.5	30.2	79.0	19.9	51.370	25.170	15.364	740 - 940
Wendover	36.7	27.7	79.7	21.6	46.819	30.035	16.085	---
VERMONT								
Burlington	31.3	33.1	74.8	16.7	65.598	22.432	15.368	---
VIRGINIA								
Richmond	40.9	20.9	77.8	26.8	30.585	60.639	15.122	1,010 - 1,285
Roanoke	39.8	23.4	78.9	26.3	35.634	45.823	15.287	940 - 1,200
WASHINGTON								
Seattle	43.7	37.3	70.9	9.4	48.945	15.768	25.142	580 - 735
Spokane	36.6	34.8	76.1	15.6	59.007	19.325	16.884	590 - 755
WEST VIRGINIA								
Charleston	38.4	23.7	78.4	26.1	37.882	46.953	14.291	910 - 1,159
Clarksburg	36.5	29.1	75.2	22.5	49.499	35.264	15.430	---
WISCONSIN								
Madison	31.5	30.7	76.9	20.2	60.510	34.867	12.672	710 - 900
Green Bay	31.1	33.0	75.2	17.5	65.576	29.028	13.512	565 - 715
Milwaukee	33.0	30.0	77.0	20.9	56.700	38.700	12.400	670 - 855

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD2. Weather Data (Including EIH, EIC, ESF) - Continued

State/ City	Winter		Summer		Energy Index			
	Avg Db Winter Temp	Length in Weeks	Avg Db Summer Temp	Length in Weeks	10^6 BTU* Outside Air Heating Load (EIH)	10^6 BTU** Outside Air Cooling Load (EIC)	10^6 BTU** Economizer Savings (ESF)	Equiv Full Load Clg Hours
WYOMING								
Casper	33.6	33.5	78.3	19.2	62.230	23.792	15.695	605 - 770
Cheyenne	34.4	33.9	76.0	18.3	61.508	21.923	18.224	580 - 740
Rock Springs	31.7	35.3	75.3	16.7	69.195	17.716	16.718	---

* Btus per season, for heating 1,000 cfm to 68°F, based on 50 hr/wk operation.
**Btus per season, for cooling 1,000 cfm to 55°F, based on 50 hr/wk operation.

Table SD3. Thermal Transmission Factor (TTF)

The Thermal Transmission Factor (TTF) is a predetermined value. Use the value that matches your building description most closely.

Building Description	TTF Value	Exterior Wall Construction	Fenestration*	Roof Construction
Low-Rise	0.48	1/2-inch lapped wood siding; 1/2-inch plywood sheathing; 2-inch x 4-inch stud framing (16-inch c.c.); 2-1/4-inch fiberglass insulation; 1/2-inch Gypsum wallboard.	Single-strength sheet; 30% sidewalls; 0% end walls.	Asphalt shingles; 1/2-inch plywood sheathing 3-1/2-inch fiberglass insulation; gypsum wallboard; ventilated attic; roof slope 3-inch/12-inch.
Low-Rise	0.77	4-inch common brick; 1/2-inch plywood sheathing; light framing; no insulation 1/2-inch gypsum wallboard.	Single-strength sheet; 30% sidewalls; 0% end walls.	Asphalt shingles; 1/2-inch plywood sheathing 3-inch fiberglass insulation; 1/2-inch gypsum wallboard; ventilated attic; roof slope 3-inch/12-inch.
Office Building	0.69	6-inch precast concrete panels.	1/4-inch plate; 30% all walls.	Four-ply built-up roofing with gravel 2-inch rigid insulation; steel decking; open web joists; 1/2-inch softboard.
Office Building	0.81	1-inch insulated sandwich panel with aluminum mullions; structural steel framing.	1/4-inch plate; 50% all walls.	Metal deck; 4-inch poured concrete roofing; structural steel framing; 1/2-inch softwood hung ceiling.
Retail Store	2.00	12-inch concrete block, painted both sides.	1/4-inch plate; 60% south wall; 0% all other walls.	Four-ply built-up roofing with gravel 2-inch rigid insulation; steel decking; open web joists; 1/2-inch softboard.
School	0.71	4-inch common brick, 1-inch fiberglass insulation 4-inch concrete block.	Single-strength sheet; 20% all walls.	Four-ply built-up roofing with gravel 2-inch rigid insulation; steel decking; open web joists; 1/2-inch softboard.
School	1.10	4-inch common brick, no insulation; 4-inch concrete block.	Single-strength sheet; 20% all walls.	Four-ply built-up roofing with gravel 1-inch rigid insulation; 4-inch concrete plant; structural steel framing, 1/2-inch softboard.

* Fenestration is defined as the arrangement and design of windows.

GLOSSARY

A = surface area of tank in ft^2.

ACWT = average condenser inlet water temperature possible, in °F (see SD 1-2).

AEI = adjusted efficiency increase of the chiller due to condenser water reset.

AND = total annual number of days that morning warmup is required expressed in days per year (see SD 1-3).

AST = average summer temperature in °F (see SD 1-4).

AWT = average winter temperature in °F (see SD 1-5).

AZ = area of zone being serviced in ft^2.

BTT = building thermal transmission factor in Btu/hr-°F-ft^2 (see SD 2-2).

C = cost of implementation ("one-time" costs). Includes planning, design, material, labor, and any test and checkout.

CAP = maximum capacity of device(s) in Btu/hr.

CD = fraction of total air passing through the cold deck. Assume 0.50 if no other information is available.

CFLH = equivalent full-load hours for cooling in hours/year (see SD 1-6).

CFM = air handling capacity in ft^3/min.

CH = present cooldown time before occupancy in hours per day. Use either the actual time presently scheduled for cooldown by an existing timeclock or 2 hours to correspond to Scheduled Start/Stop savings calculations.

CPT = energy consumption per ton of refrigeration in kw/ton or lb/ton-hr = 12/EER (see SD 2-4).

CU = coefficient of utilization. Typical value = 0.62, for additional values consult table 11.

D = diameter of tank in ft.

DAY = equipment operation in days per week.

E = parameter determined from nomograph 23.

EER = cooling energy efficiency ratio in Btu per watt-hr = 12/CPT (see SD 2-4).

EI = efficiency increase expressed as a decimal (use 0.01 if no better estimate is available).

EIC = cooling energy index. Btu per season for cooling 1,000 cfm to 55°F, based on 50 hours a week of HVAC system operation (see table SD2).

EIH = heating energy index. Btu per season for heating 1,000 cfm to 68°F, based on 50 hours a week of HVAC system operation (see table SD2).

ERT = equipment run time, total required for warmup in hours per year (see SD 2-3).

ES = energy saved in MBtu or kwh.

ESA = energy savings associated with operation of auxiliary equipment, in kwh.

ESC = electrical energy saved for cooling, in kwh.

ESF = economizer savings factor. Btu per year per 1,000 cfm, based on enthalpy (vice dry bulb temperature), air selection, and 50 hours per week of HVAC system operation (see table SD2).

ESH = energy saved for heating in MBtu.

F = loss factor expressed in Btu/°F-hr-ft^3.

FA = percent of makeup air (outside air) necessary to meet minimum ventilation requirements (percent total flow rate).

H = hours of operation per week.

HAP = air purge period time in hours per week.

HCD = operating hours per week during which the makeup air (outside air) damper is closed.

HD = fraction of total air passing through the hot deck. Assume 0.50 if no other information is available.

HEFF = heating efficiency of the system (see SD 2-4).

HFLH = annual equivalent full-load hours for heating in hours per year (see SD 1-7).

HOD = operating hours per week during which the makeup air (outside air) damper is open.

HP = motor nameplate horsepower.

HPW = actual (measured) horsepower.

HS = hours in summer during which outside temperature is below summer thermostat set (78°F) limit in hours per year (see SD 1-8).

HT = height of tank in ft.

HV = heating value of fuel in Btu/gal, Btu/kwh, etc. (see SD 2-4).

HW = hours in winter during which outside temperature is above winter thermostat set limit (65°F) in hours per year (see SD 1-8).

INS = thickness of insulation in inches.

KW_L = total killowatt consumption of lights in the zone.

L = load factor (see SD 2-4).

LLF = light loss factor "maintenance factor", typical value = 0.65

LS = summer loading factor, equals CFLH/52. Use 1 for hot/cold deck systems not using cold deck reset.

LSD = length of shutdown period in hours.

LTL = low temperature limit in °F; usually 50°F or 55°F. Use the average winter temperature in place of LTL if AWT < LTL.

NES = national energy savings in Btu/yr. It is the Btu value of hydrocarbon fuel saved as a consequence of a conservation measure (regardless of whether the fuel would have been used directly, or used to produce the electricity).

NES = Hydrocarbon Fuel Savings (in Btu/yr) +
(Electrical Energy Savings (in kwh/yr) x
11,600 Btu/kwh)

The 11,600/kwh factor accounts for the losses in fuel combustion, conversion of heat energy to mechanical energy, and transmission losses involved in the production and distribution of electrical energy from oxidation of hydrocarbon fuels.

NSD = number of shutdown periods of a given length per year.

OAH = average outside air enthalpy in Btu/lb (see SD 1-9).

PCWT = present condenser water temperature in °F usually set at 85°F.

PEI = percent efficiency increase of the chiller.

POA = present percent minimum outside air expressed as a decimal.

PRT = percent run time during heating season shutdown period required to maintain a low limit temperature of 55°F (see SD 1-10). Use PRT = 0 if no low temperature limit is planned.

RAH = return air enthalpy. Use 29.91 Btu/lb for 78°F and 50% humidity. For other conditions obtain values from a psychrometric chart.

RCWT = reduction in condenser water temperature in °F.

REI = rate of efficiency increase per °F increase of chilled water temperature.

Use for

screw compressor machine	- 0.024 per °F
centrifugal (elec. or turbine) machine	- 0.017 per °F
reciprocal machine	- 0.012 per °F
absorption machine	- 0.006 per °F

RF = reset factor. (subscripts c and h may be used to denote cooling or heating season).

RH = reheat reset factor (see HVAC 17). Subscripts c and h may be used to denote cooling or heating season value.

RHR = reheat system cooling coil discharge reset in °F. Up to 5° or 6° is possible, dependent on the system. If a better estimate of possible reset is not available, use 3°F.

SB = thermostat setback for unoccupied periods during the heating season in °F.

SCDR = summer cold deck reset in °F (the average reset that will result from this function is dependent on the air handler capacity relative to the loads in the space it serves. If an estimate of the possible reset is not available, use 2°F).

SHDR = summer hot deck reset in °F (the average reset that will result from this function is dependent on the air handler capacity relative to the loads in the space it serves. If an estimate of the possible reset is not available, use 3°F).

SSP = summer thermostat setpoint in °F normally 78°F.

SU = thermostat setpoint for unoccupied periods during the cooling season in °F.

T = water temperature at end of shutdown period in °F.

To = hot water temperature setpoint in °F.

TON = chiller capacity in tons.

Ts = average temperature of surroundings in °F.

UH = unoccupied hours per week.

GLOSSARY - CONTINUED

V = volume of tank in ft^3.

WH = morning warmup time before occupancy in hours per day.

WHDR = winter hot deck reset in ^oF (the average reset is a function of the system. If an estimate is not available use 2^oF).

WKS = length of summer cooling season in weeks per year (see SD 1-11).

WKW = length of winter heating season in weeks per year (see SD 1-11).

WSP = winter thermostat setpoint in ^oF normally 65^oF.

TABLE OF CONTENTS

NOMOGRAPHS

Nomograph 1 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 geographic locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat losses are based on a 68°F indoor temperature.

The solar effect on a wall was calculated by the computer using sol-air temperature, and the heat entering or leaving a space was calculated with the equivalent temperature difference. Wall mass ranged from 50 to 60 pounds per square foot and thermal lag averaged 4-1/2 hours. Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10%; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. The heat losses assume that the walls are subjected to direct sunlight. If shaded, losses should be read from the north exposure line.

Instructions for use of nomograph 1:

1. Confirm that local latitude falls within range of the nomograph.

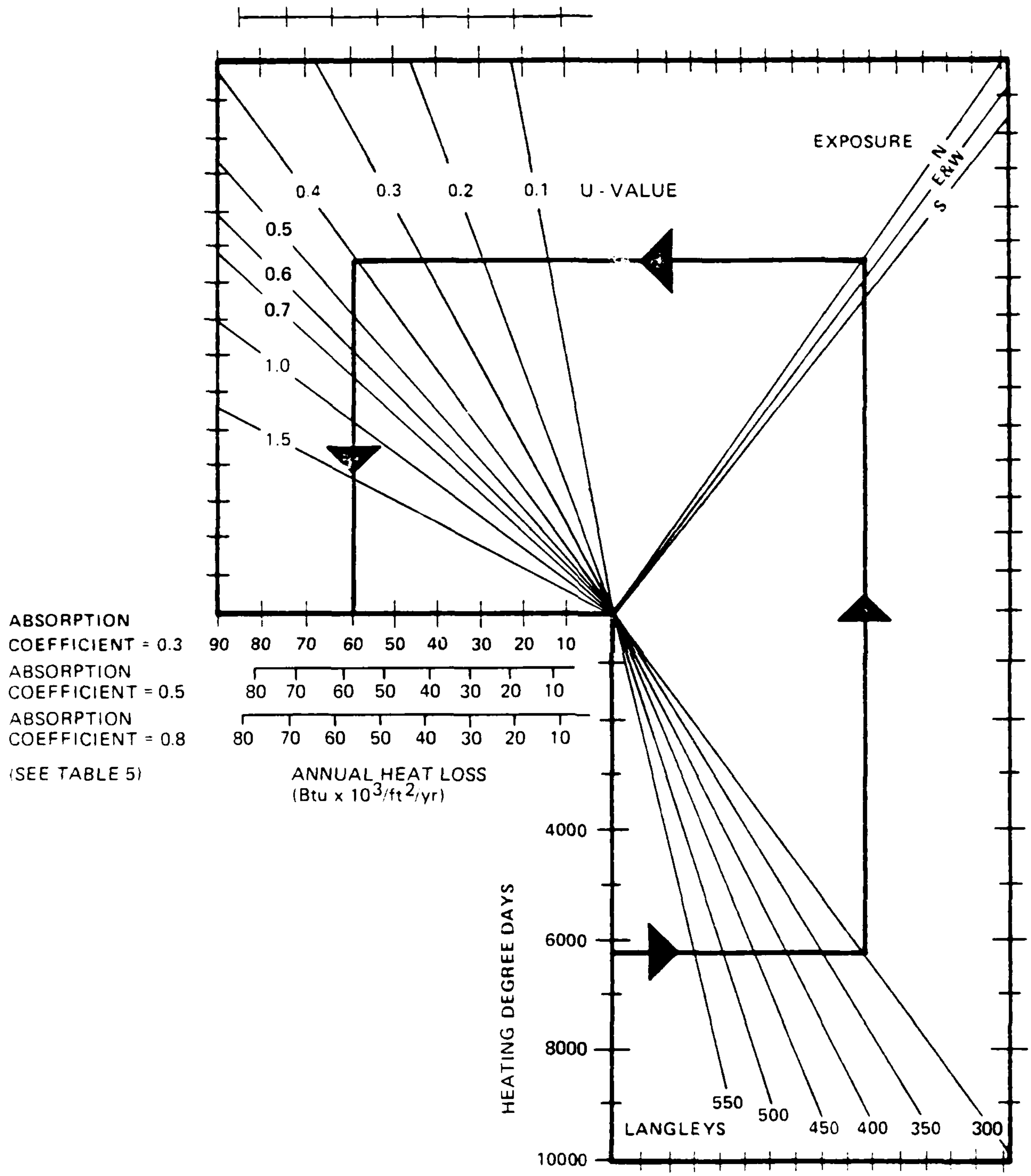
2. Enter the nomograph on the bottom left-hand vertical line at the degree-days.

3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated.

5. Proceed horizontally left from this intersection to the U-value.

6. Proceed vertically downward at this intersection to the proper scale for the absorption coefficient as indicated by the type of wall. Read the yearly loss in Btu x 10^3 per square foot.



Nomograph 1. Heating - Annual Heat Loss Through Walls Latitude 25°N - 35°N

Nomograph 2 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat losses are based on a 68°F indoor temperature.

The solar effect on a wall was calculated by the computer using sol-air temperature, and the heat entering or leaving a space was calculated with the equivalent temperature difference. Wall mass ranged from 50 to 60 pounds per square foot and thermal lag averaged 4-1/2 hours. Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10%; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. The heat gains assume that the walls are subjected to direct sunlight. If shaded, losses should be read from the north exposure line.

Instructions for use of nomograph 2:

1. Confirm that local latitude falls within range of the nomograph.

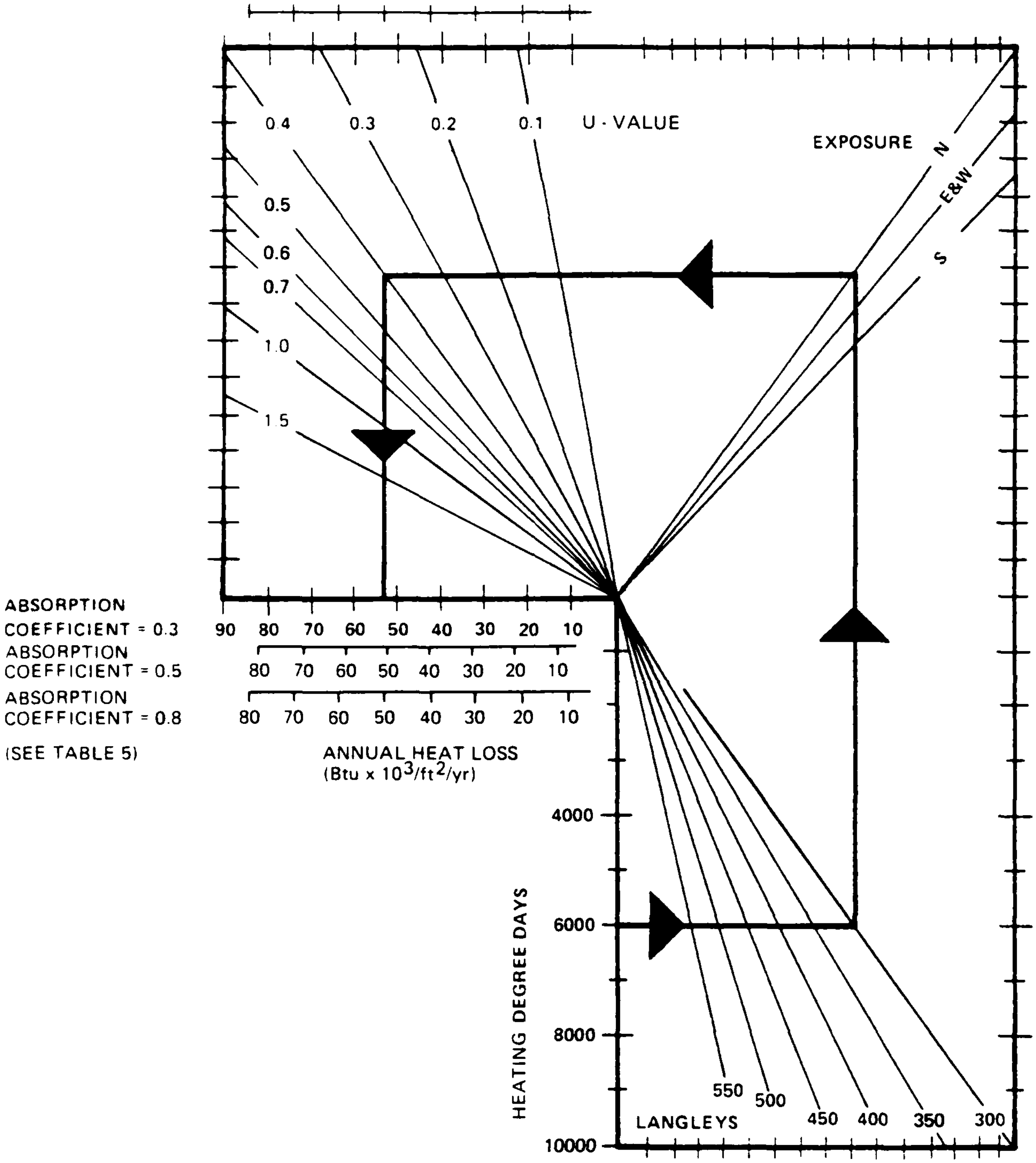
2. Enter the nomograph on the bottom left-hand vertical line at the degree-days.

3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated.

5. Proceed horizontally left from this intersection to the U-value.

6. Proceed vertically downward from this intersection to the proper scale for the absorption coefficient as indicated by the type of wall. Read the yearly loss in Btu x 10^3 per square foot.



Nomograph 2. Heating - Annual Heat Loss Through Walls Latitude 35°N - 45°N

Nomograph 3 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat losses are based on a 68°F indoor temperature.

The solar effect on a wall was calculated by the computer using sol-air temperature, and the heat entering or leaving a space was calculated with the equivalent temperature difference. Roof mass ranged from 25 to 35 pounds per square foot and thermal lag averaged 3-1/2 hours. Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot, 2) outdoor air ventilation rate of 10%, and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the cooling season.

Absorption coefficients and U-values were varied and summarized for the 12 locations as shown in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56. The data was then plotted and extrapolated to include the entire range of degree-days.

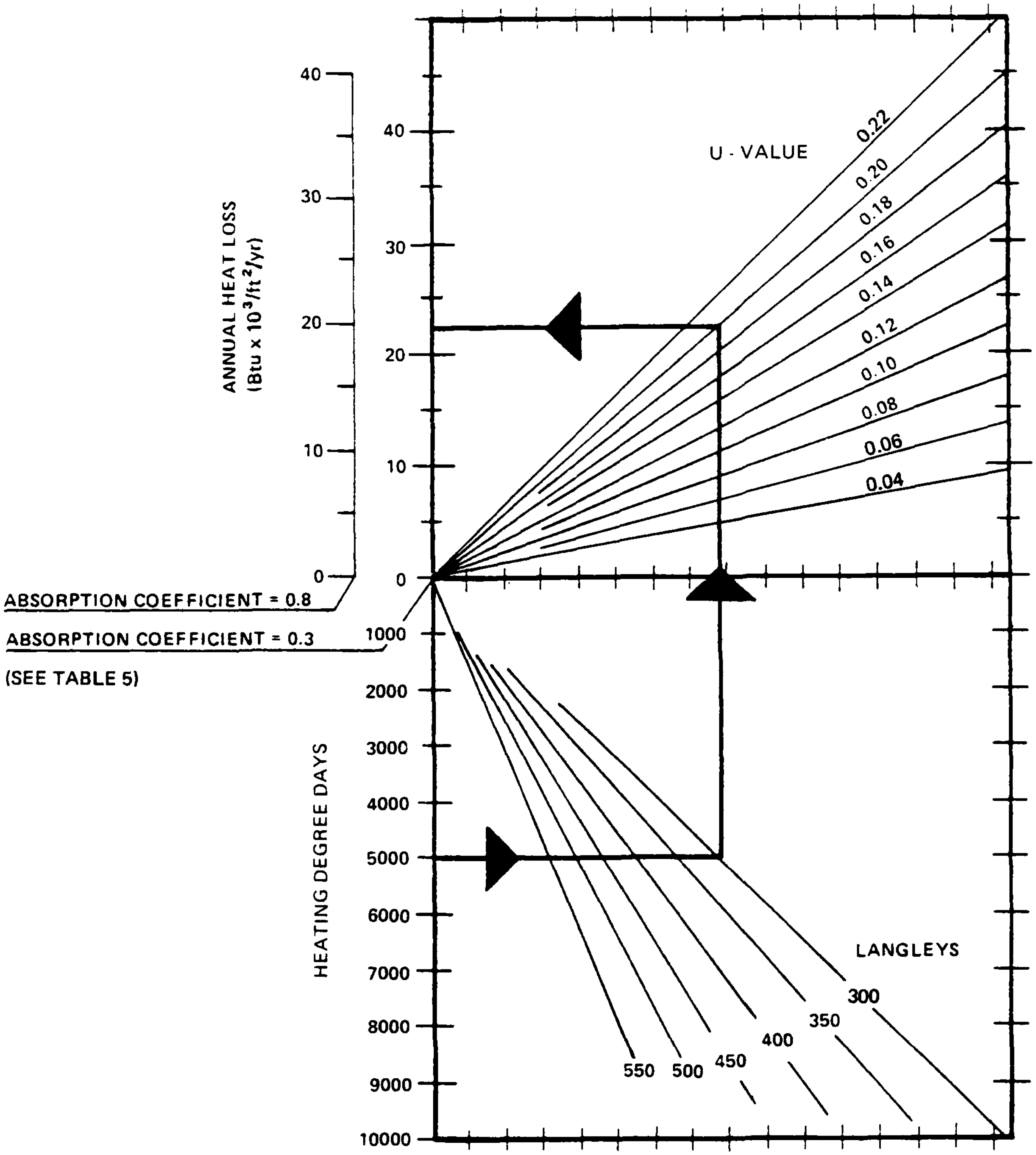
Instructions for use of nomograph 3:

1. Enter the nomograph on the bottom left-hand vertical line at the degree-days.

2. Proceed horizontally right to the number of Langleys.

3. Proceed vertically upward from this intersection to the U-value.

4. Proceed horizontally left at this intersection to the proper scale. Read the yearly heat loss in Btu x 10^3 per square foot.



Nomograph 3. Heating - Annual Heat Loss Through Roof

Nomograph 4 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

Heat losses determined from this nomograph are based on the assumption that the floor is over an unheated space which is at outdoor ambient air temperature. Since the load on the heating system during occupied hours is generally a small percentage of the total annual heating load, the figure gives heat loss during unoccupied times only, with 10 hours of occupied time per week being the maximum (158 hours unoccupied). It was also assumed that the temperature during the unoccupied time is set back to 55°F and, since heating degree days are based on 65°F, all losses were multiplied by a factor of 55/65. Thus the formula the figure is based on is:

$$Q(\text{heat loss}) = \text{Heating Degree Days} \times 24 \times \text{U-value} \times 55/65 \times \frac{\text{Unoccupied Hours}}{168}$$

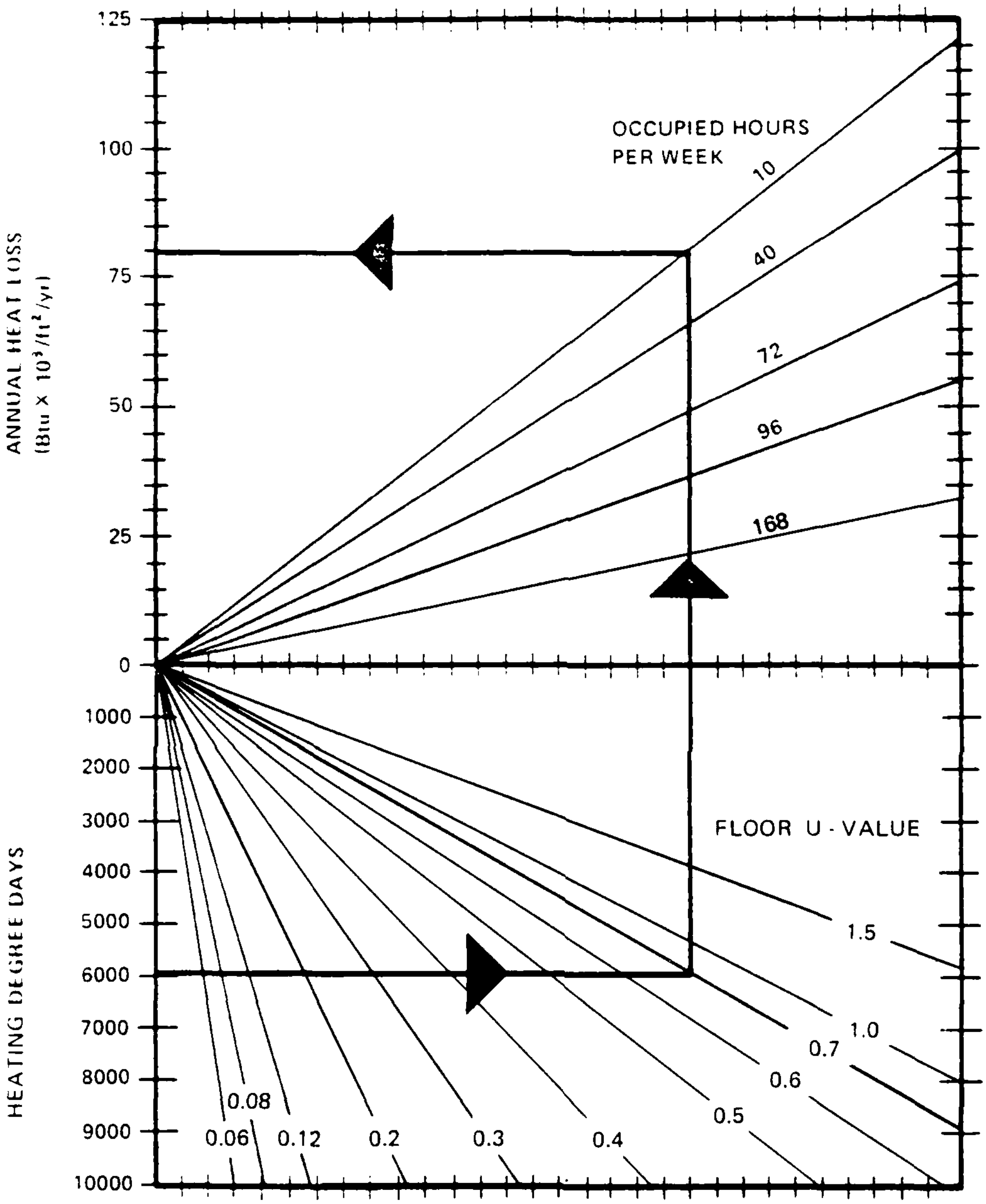
Instructions for use of nomograph 4:

1. Enter the nomograph on lower left-hand vertical line at the heating degree days.

2. Proceed horizontally right to the intersection with the floor U-value.

3. Proceed vertically upward from this intersection to the number of occupied hours per week.

4. Proceed horizontally left from this intersection to the proper scale. Read the annual heat loss in Btu x 10^3 per square foot.



Nomograph 4. Heating - Annual Heat Loss Through Floors Exposed to Outdoor Temperatures

Nomograph 5 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature.

The solar effect was calculated using sol-air temperature, and the heat entering or leaving a space was calculated with the equivalent temperature difference. Wall mass ranged from 50 to 60 pounds per square foot and thermal lag averaged 4-1/2 hours. During this cooling season internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat going through the walls was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

Instructions for use of nomograph 5:

1. Confirm that local latitude falls within range of the nomograph.

2. Enter the nomograph on the bottom left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

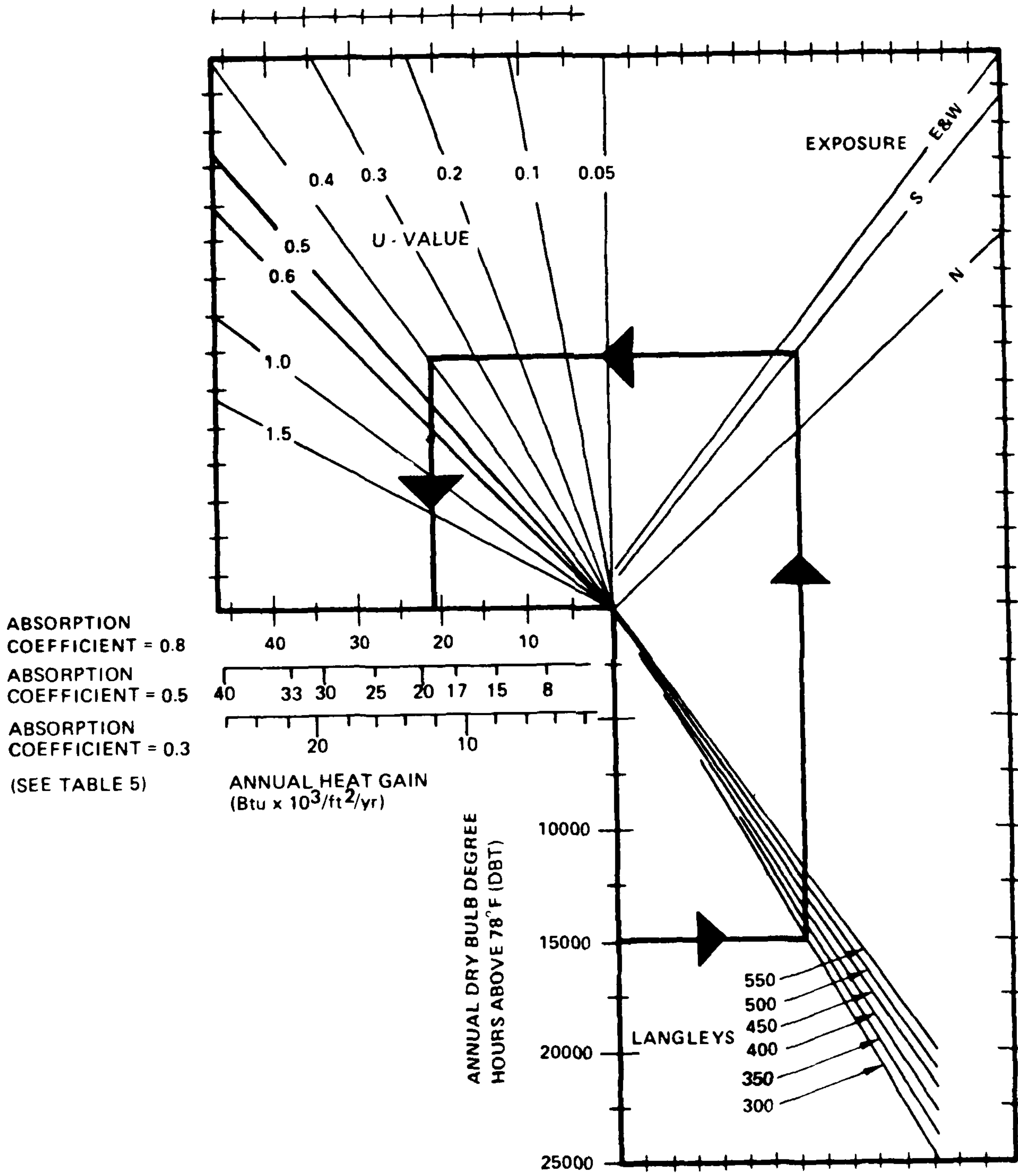
3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation (exposure) being investigated.

5. Proceed horizontally left from this intersection to read the U-value for the walls.

6. Proceed vertically downward from this intersection to the proper scale.

7. Read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 5. Cooling - Annual Solar Heat Gain Through Walls (or Windows with Insulating Drapes) Latitude 25°N - 35°N

Nomograph 6 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature.

The solar effect on a wall was calculated using sol-air temperature, and the heat entering or leaving a space was calculated with the equivalent temperature difference. Wall mass ranged from 50 to 60 pounds per square foot and thermal lag averaged 4-1/2 hours. During the cooling season, internal gains, ventilation infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the walls was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season. The heat losses assume that the walls are subjected to direct sunlight. If shaded, losses should be read from the north exposure line.

Instructions for use of nomograph 6:

1. Confirm that local latitude falls within range of the nomograph.

2. Enter the nomograph on the lower left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

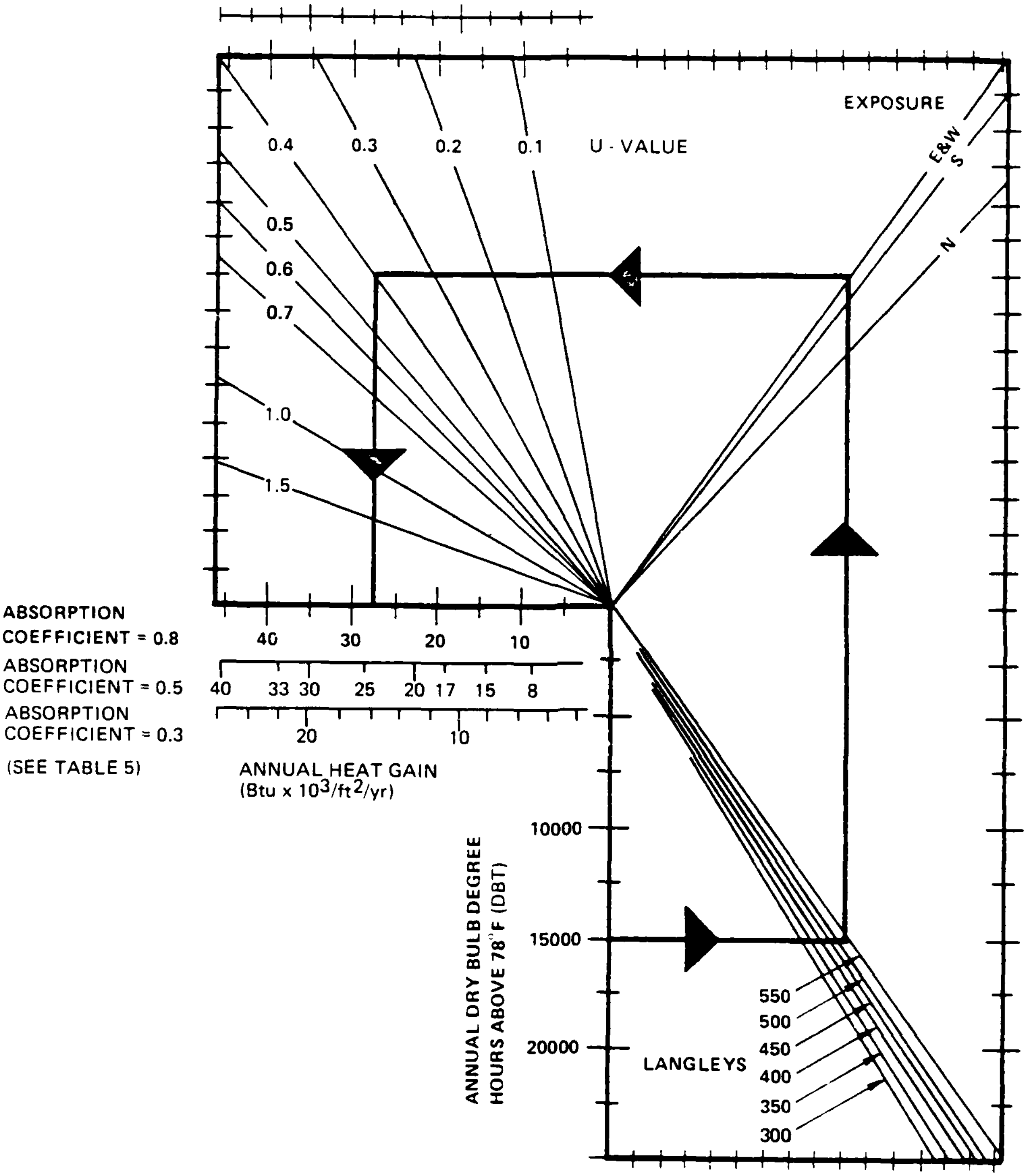
3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated.

5. Proceed horizontally left from this intersection to the U-value for the walls.

6. Proceed vertically downward from this intersection to the proper scale determined by the existing absorption coefficient.

7. Read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 6. Cooling - Annual Solar Heat Gain Through Walls (or Windows with Insulating Drapes) Latitude 35°N - 45°N

Nomograph 7 Engineering Data

Source of Data: <u>Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)</u>

This nomograph is based on degree hours read from Map 3 (see Supporting Data), which has a base of 56 hours/week. The nomograph is based on the formula:

Q = (Heat Gain)/yr = Degree Hours/yr x U-value

The major portion of degree hours occur between 10 a.m. and 3 p.m. Hence for occupancies between 10 and 56 hours per week, the degree hour distribution can be assumed to be linear. However, for occupancies greater than 54 hours per week, the degree hour distribution becomes nonlinear, particularly in locations with greater than 15,000 degree hours. This is reflected by the curves for 72 and 96 hours per week occupancies.

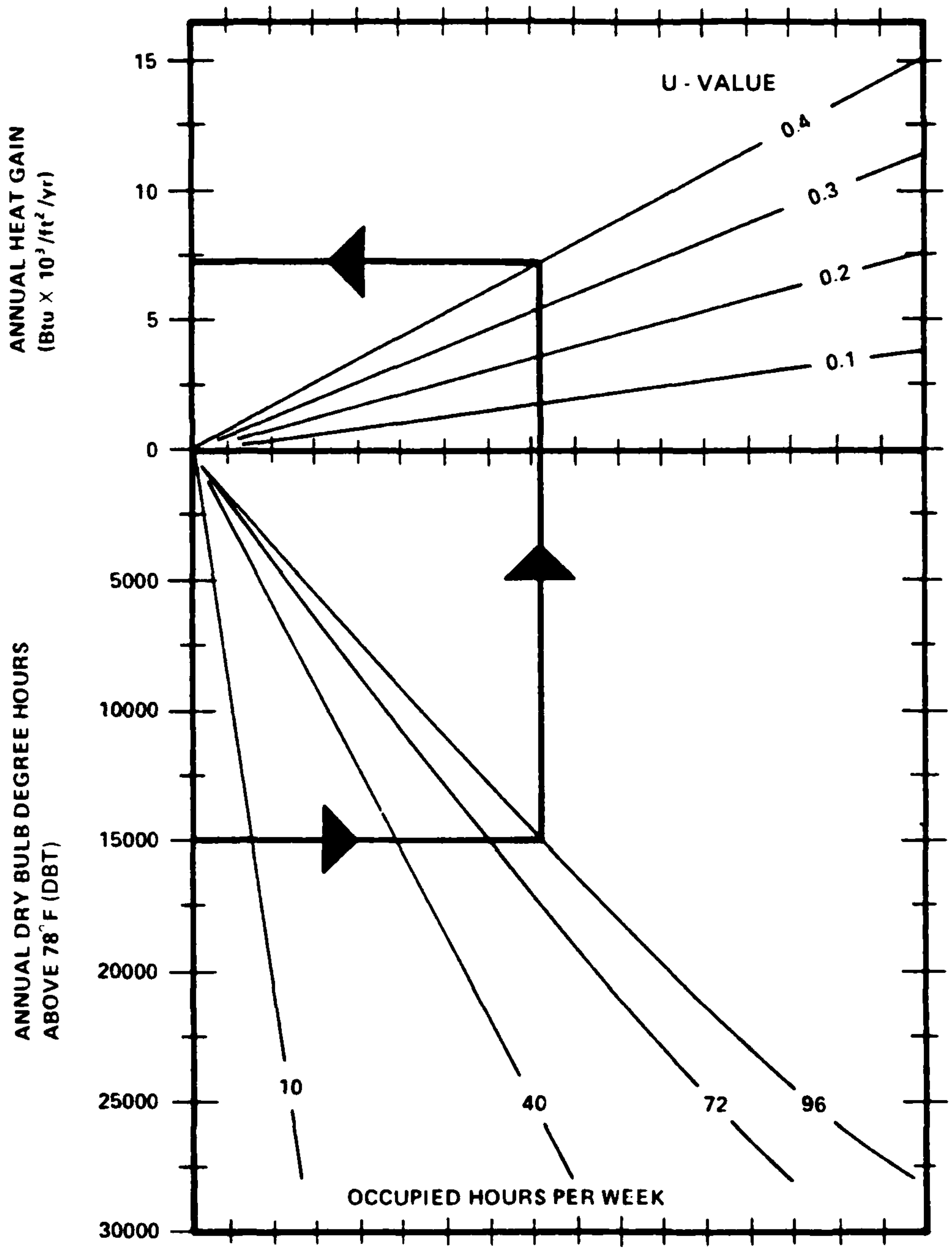
Instructions for use of nomograph 7:

1. Enter the nomograph on the lower left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

2. Proceed horizontally right to the number of occupied hours per wee .

3. Proceed vertically upward from this intersection to the U-value.

4. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 7. Cooling - Annual Conduction Heat Gain Through Walls, Roofs, and Floors

Nomograph 8 Engineering Data

Source of Data: <u>Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)</u>

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat losses are based on a 78°F indoor temperature.

The solar effect on a wall was calculated by the computer using sol-air temperature, and entering or leaving a space was calculated with the equivalent temperature difference. Roof mass ranged from 25 to 35 pounds per square foot and thermal lag averaged 3-1/2 hours. During the cooling season, internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the roof was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

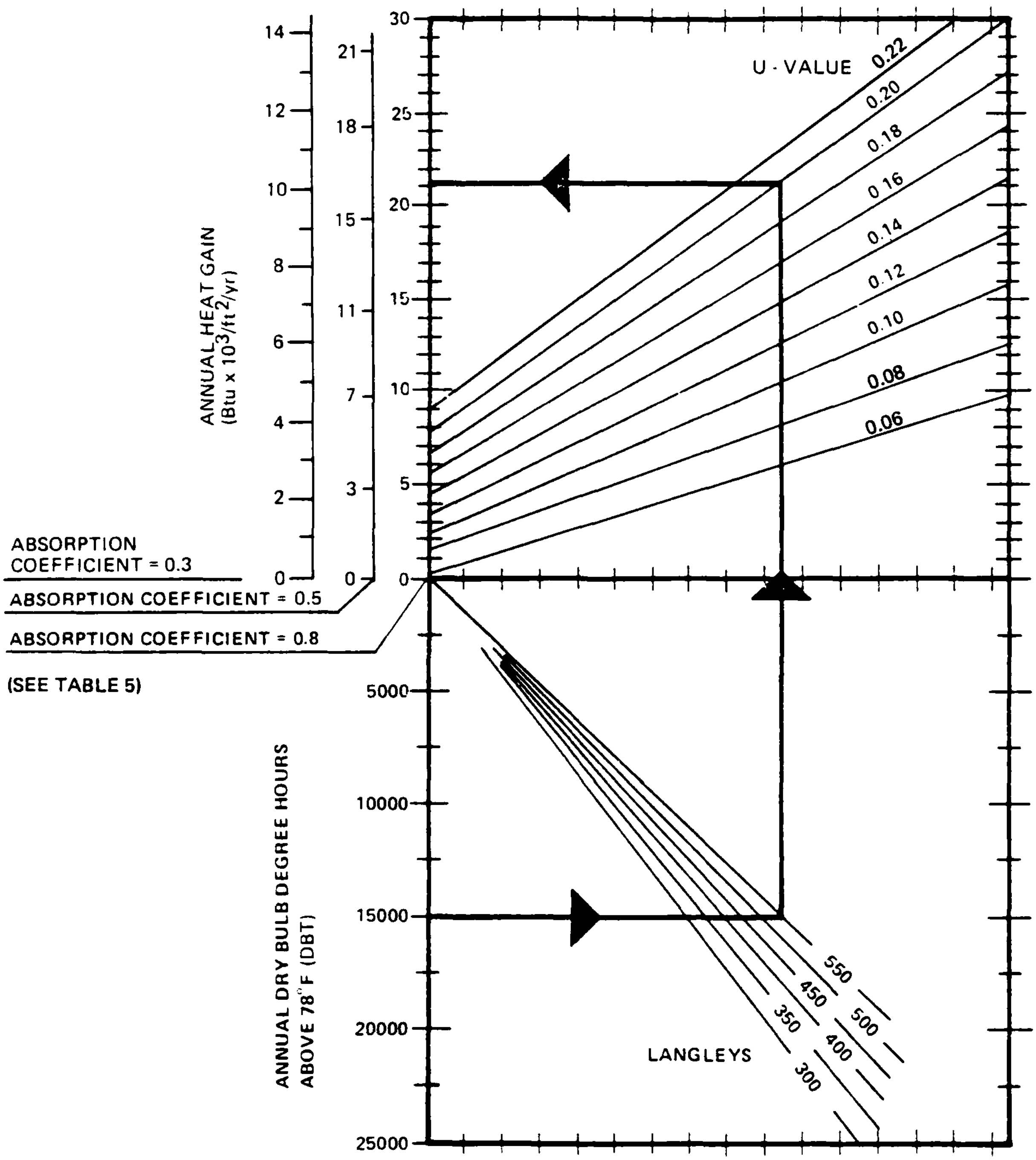
Instructions for use of nomograph 8:

1. Enter the nomograph on the bottom left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

2. Proceed horizontally right to the number of Langleys.

3. Proceed vertically upward from this intersection to the U-value.

4. Proceed horizontally left from this intersection to the proper scale. Read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 8. Cooling - Annual Solar Heat Gain Through Roof

Nomograph 9 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature. During the cooling season, internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the windows was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. Increases in the conduction heat gain through windows, determined using nomograph 11, were deducted from the total heat gains to derive the solar component. The solar component was then plotted and extrapolated to include the entire range of degree hours. Nomograph 9 was derived from locations with latitudes between 25 and 35 degrees north. The heat gains assume that the windows are subjected to direct sunshine. If shaded, gains should be read from the north exposure line. The accuracy of the graph diminishes for locations with less than 5,000 degree hours.

Instructions for use of nomograph 9:

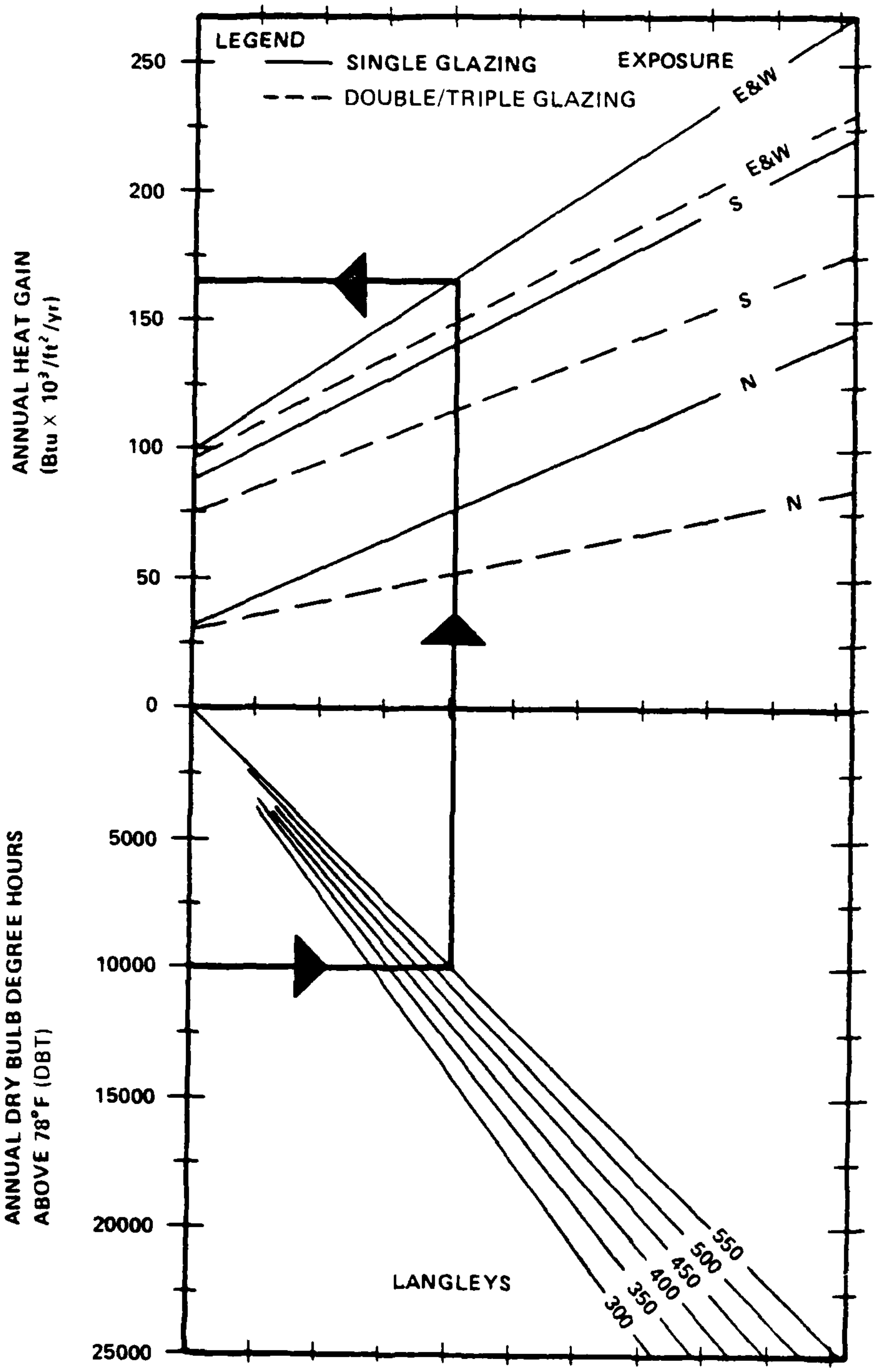
1. Confirm that local latitude falls within the range of the nomograph.

2. Enter the nomograph on the bottom left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 9. Cooling - Annual Solar Heat Gain Through Windows Latitude 25°N - 35°N

Nomograph 10 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature. During the cooling season, internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the windows was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. Increases in the conduction heat gain through windows, determined using nomograph 11, were deducted from the total heat gains to derive the solar component. The solar component was then plotted and extrapolated to include the entire range of degree-hours. Nomograph 11 was derived from locations with latitudes between 25 and 35 degrees north. The heat gains assume that the windows are subjected to direct sunshine. If shaded, gains should be read from the north exposure line. The accuracy of the graph diminishes for locations with less than 5,000 degree-hours.

Instructions for use of nomograph 10:

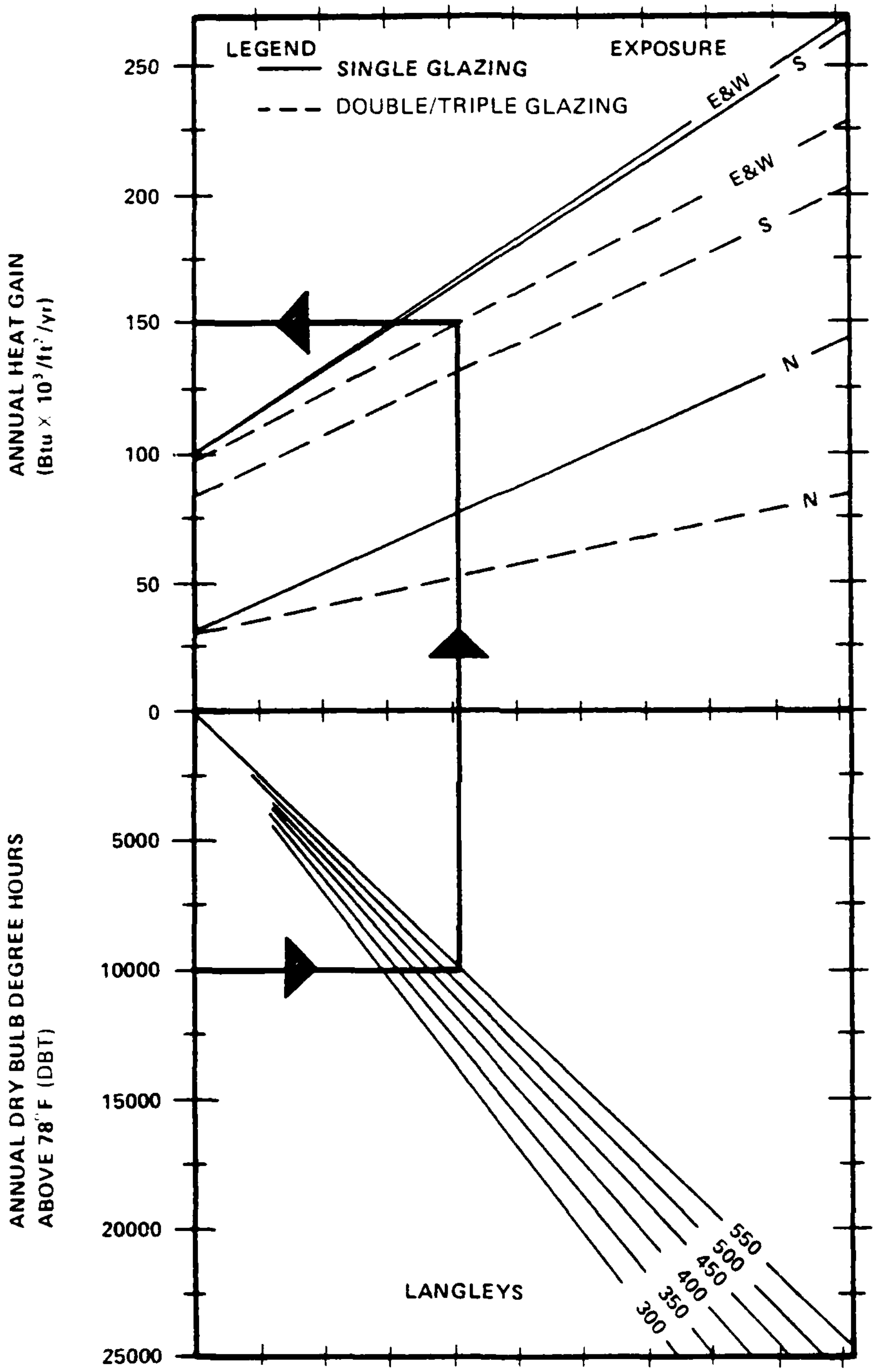
1. Confirm that local latitude falls within the range of the nomograph.

2. Enter the nomograph on the bottom left-hand vertical line at the annual dry bulb degree hours above 78°F (DBT).

3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to glazing.

5. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 10. Cooling - Annual Solar Heat Gain Through Windows Latitude 35°N - 45°N

Nomograph 11 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on degree hours determined using nomograph 13, which has a base of 56 hours per week. The nomograph is based on the formula:

Q (heat gain)/yr = degree hours/yr x U-value. U-values assumed were:

1.1 for single panes, 0.65 for double panes, and 0.47 for triple panes. The major portion of degree hours occur between 10 a.m. and 3 p.m. Hence, for occupancies between 10 and 56 hours per week, the degree-hour distribution can be assumed to be linear. However, for occupancies greater than 56 hours per week the degree hour distribution becomes nonlinear, particularly in locations with greater than 15,000 degree hours. This is reflected by the curves for 72 and 96 hour per week occupancies.

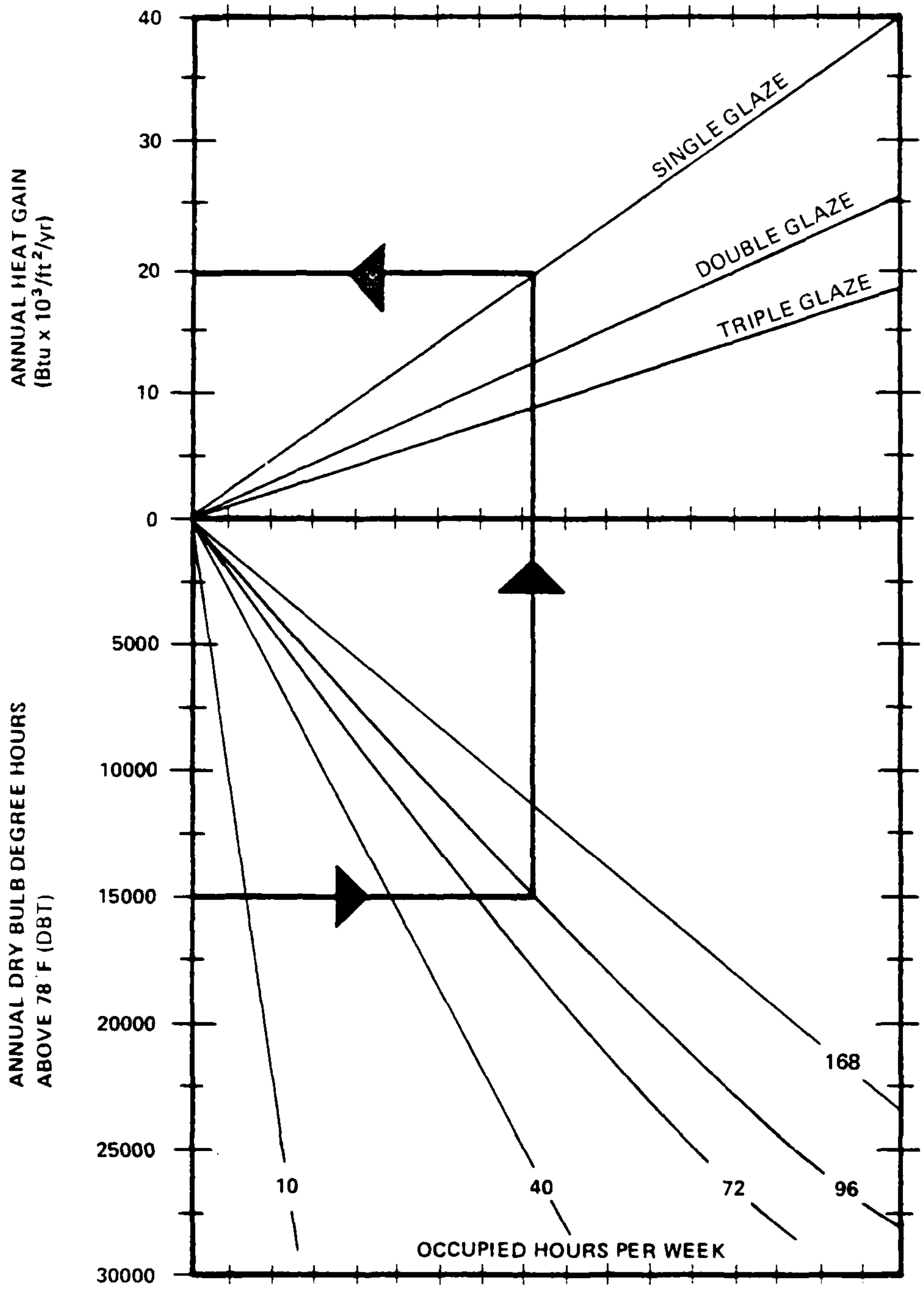
Instructions for use of nomograph 11:

1. Enter the nomograph on lower left-hand vertical line at the annual dry bulb degree hours above 78^{o}F (DBT).

2. Proceed horizontally right to the number of occupied hours per week.

3. Proceed vertically upward from this intersection to the type of existing glazing.

4. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 11. Annual Conduction Heat Gain Through Windows

Nomograph 12 Engineering Data

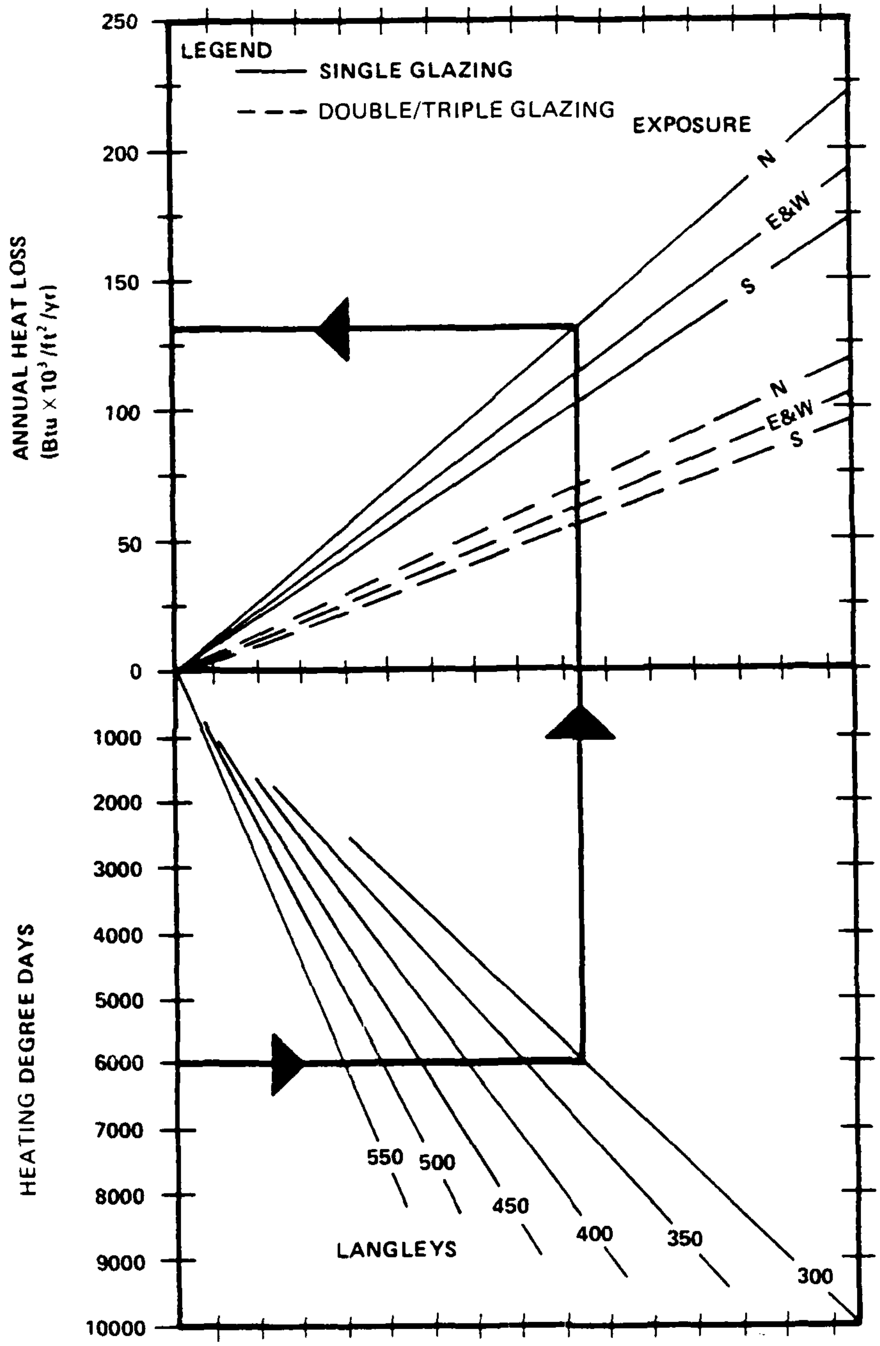
Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 68°F indoor temperature.

Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10 percent; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. The data was then plotted and extrapolated to include the entire range of degree days. Nomograph 12 was derived from locations with latitudes between 25 and 35 degrees north.

Instructions for use of nomograph 12:

1. Confirm that local latitude falls within the range of the nomograph.
2. Enter the nomograph on the bottom left-hand vertical line at the heating degree days.
3. Proceed horizontally right to the number of Langleys.
4. Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding with existing glazing.
5. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 12. Heating - Annual Heat Loss Through Windows Latitude 25°N - 35°N

Nomograph 13 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 68°F indoor temperature.

Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10 percent; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. The data was then plotted and extrapolated to include the entire range of degree days. Nomograph 13 was derived from locations with latitudes between 25 and 35 degrees north.

Instructions for use of nomograph 13:

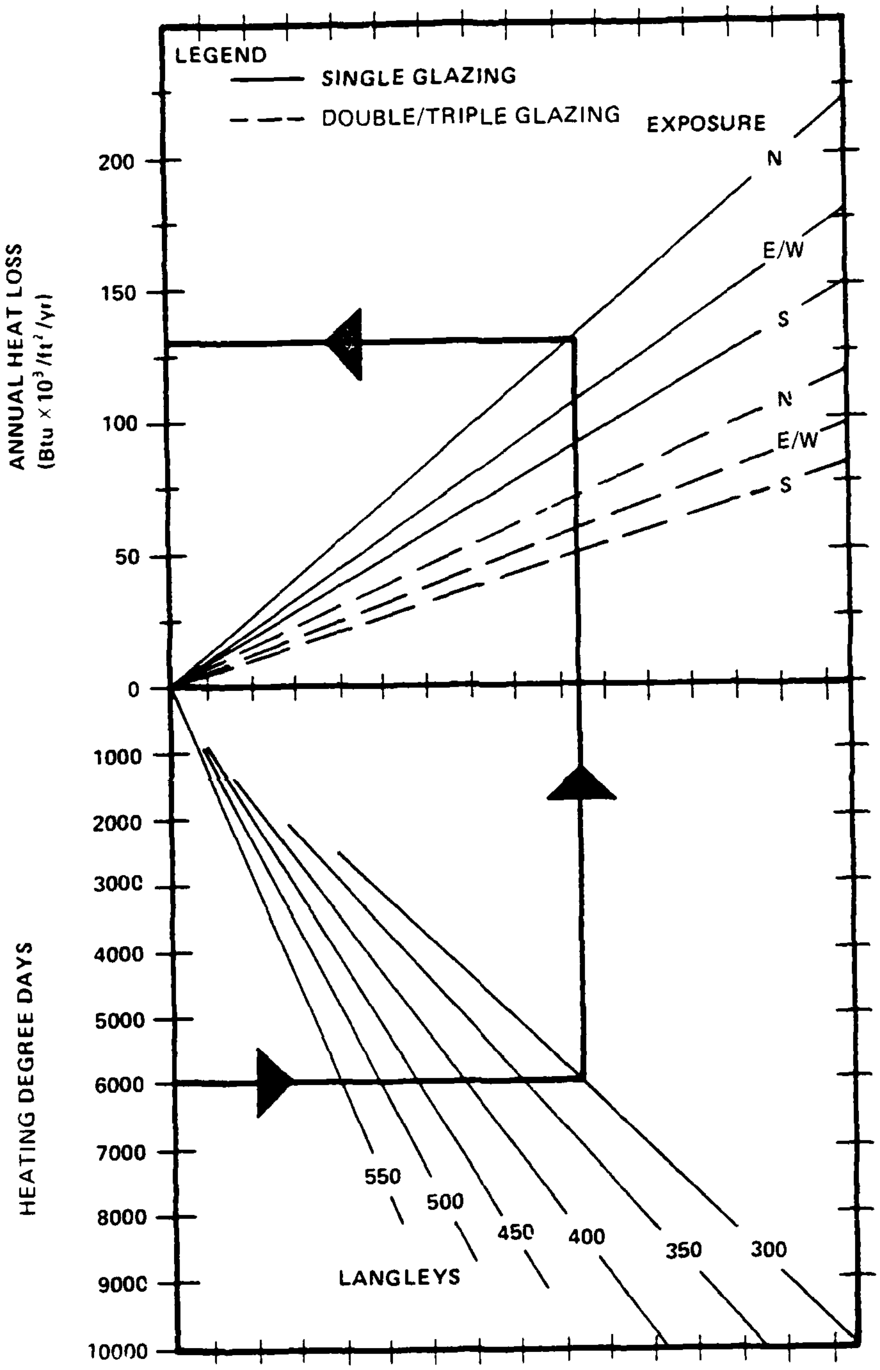
1. Confirm that local latitude falls within the range of the nomograph.

2. Enter the nomograph on the bottom left-hand vertical line at the heating degree days.

3. Proceed horizontally right to the number of Langleys.

4. Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5. Proceed horizontally left from this intersection to read the annual heat gain in Btu x 10^3 per square foot.



Nomograph 13. Heating - Annual Heat Loss Through Windows Latitude 35°N - 45°N

Nomograph 14 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

The development of this nomograph was based on the assumptions that:

1. Thermal barriers are closed only when the building is unoccupied.

2. The average heating degree day distribution is 25% during the daytime and 75% during nighttime.

The number of heating degree days occurring when the thermal barriers are closed was determined from the characteristic occupancy period shown in the figure. This can be expressed as a fraction of the total heating degree days by the relationship:

$$DD_A = 0.25\ DD_T \left[\frac{\text{Unoccupied Daytime hr/wk}}{\text{Total Daytime hr/wk}}\right] + 0.75\ DD_T \left[\frac{\text{Unoccupied Nighttime hr/wk}}{\text{Total Nighttime hr/wk}}\right]$$

Where:

DD_A = Adjusted heating degree days

DD_T = Total heating degree days

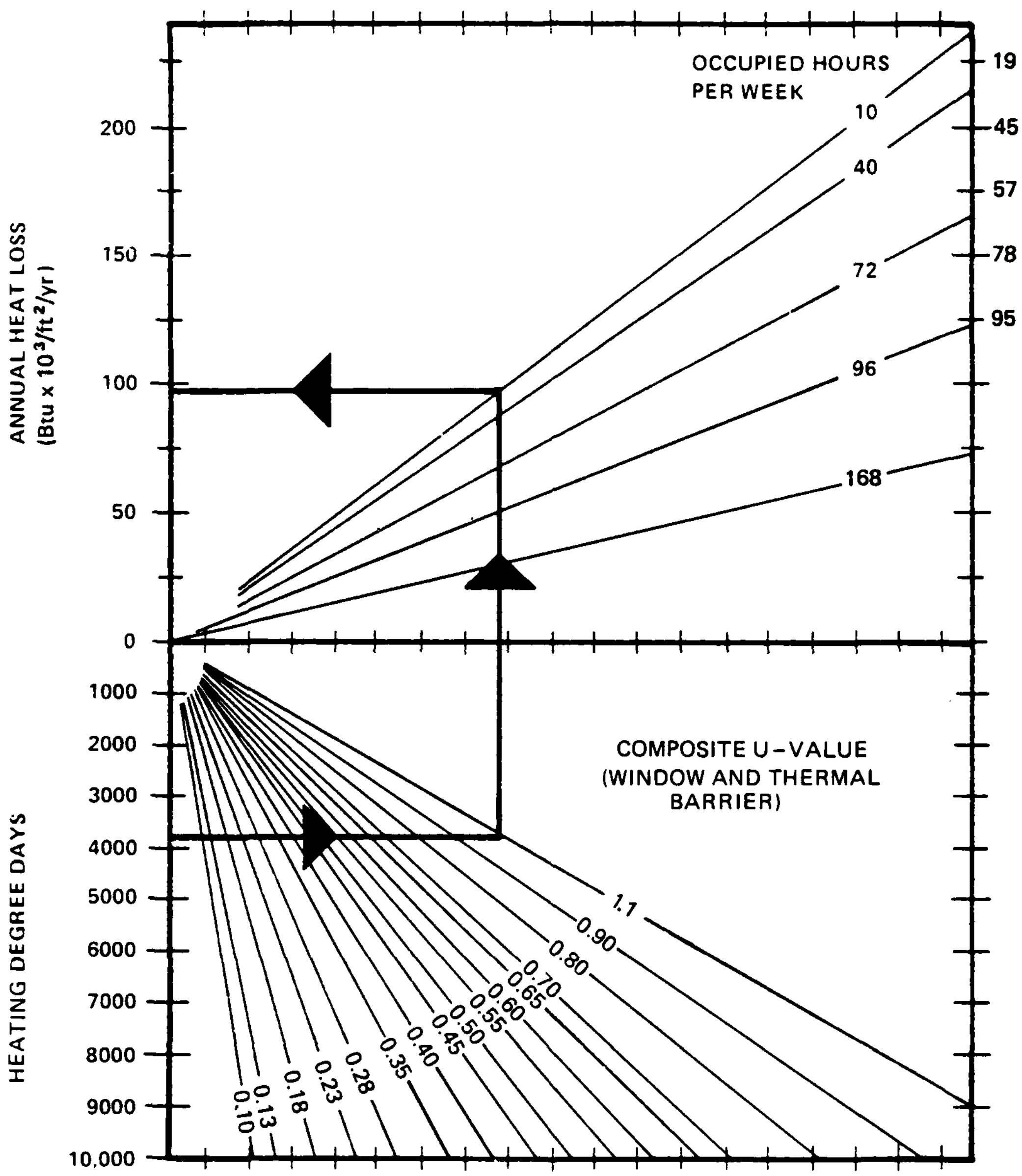
Instructions for use of nomograph 14:

1. Enter the nomograph on the bottom left-hand vertical line at the heating degree days.

2. Proceed horizontally right to the composite U-value.

3. Proceed vertically upward from this intersection to the number of occupied hours per week.

4. Proceed horizontally left from this intersection to read the annual heat loss in Btu x 10^3 per square foot.



Nomograph 14. Heating - Annual Heat Loss for Windows with Thermal Barriers

Nomograph 15 Engineering Data

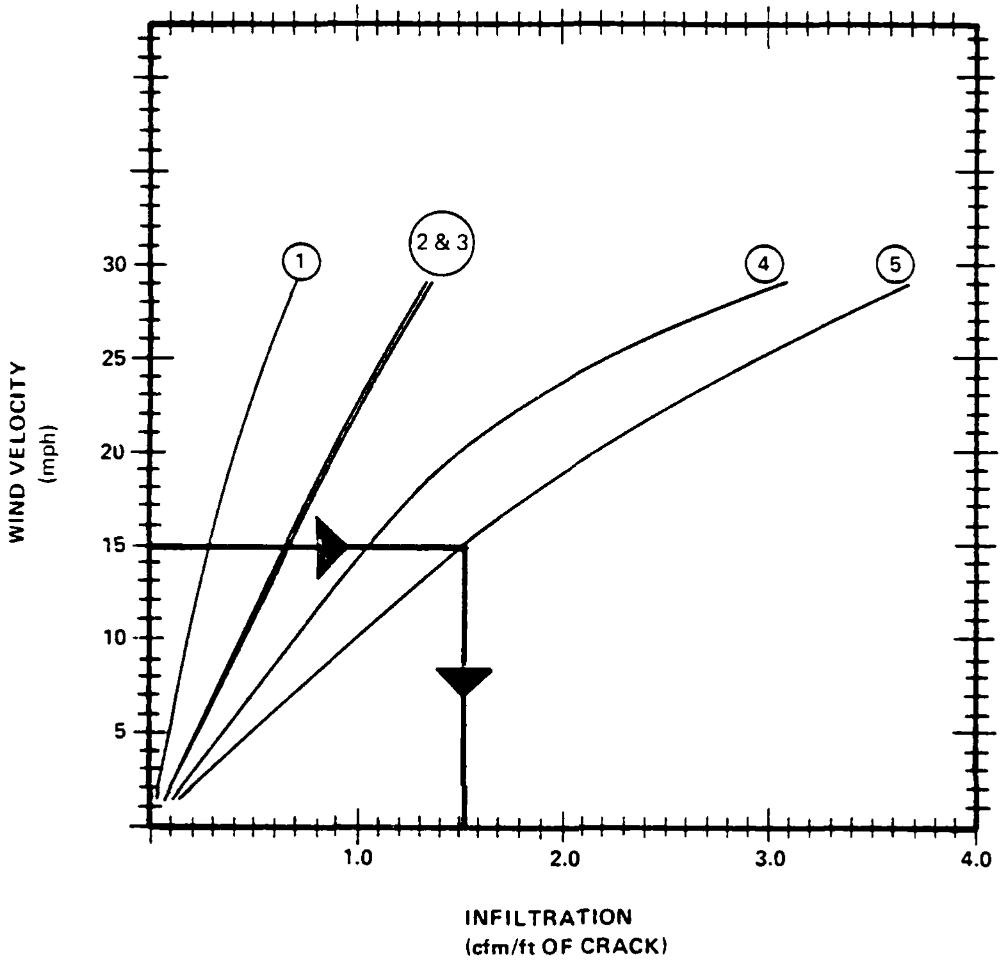
Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

Instructions for use of nomograph 15:

1. Enter the nomograph on left-hand side at wind velocity in miles per hour.

2. Proceed horizontally right to the curve that most closely fits existing conditions of the building under survey.

3. Proceed vertically downward from this intersection to read the infiltration in ft^3/min per linear foot of crack.



KEY:

NO.	TYPE	MATERIAL	WEATHER-STRIPPED	FIT
1.	ALL HINGED	WOOD METAL	YES YES	AVERAGE AVERAGE
2.	ALL HINGED DOUBLE HUNG	WOOD METAL STEEL	NO NO NO	AVERAGE AVERAGE AVERAGE
3.	ALL DOUBLE HUNG	WOOD STEEL	YES YES	LOOSE AVERAGE
4.	CASEMENT STEEL	STEEL	NO	AVERAGE
5.	ALL HINGED	WOOD	NO	LOOSE

Nomograph 15. Infiltration Through Windows

Nomograph 16 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

Energy used is a function of the number of heating degree days, indoor temperature, and the number of hours that temperature is maintained and is expressed as the energy used per 1,000 cfm of air conditioned.

The energy used per year was determined as follows:

$$Btu/yr = (1{,}000\ cfm) \times (heating\ degree\ days/yr) \times (24\ hr/day) \times (1.08\ Btu\text{-}min/ft^3\text{-}^oF\text{-}hr)^*$$

Since heating degree days are base 65^oF, the other temperatures in the lower section of the figure are directly proportional to the 65^oF line. The upper section proportions the hours of system operation with 168 hours per week being 100 percent.

*1.08 is a factor which incorporates specific heat, specific volume, and time.

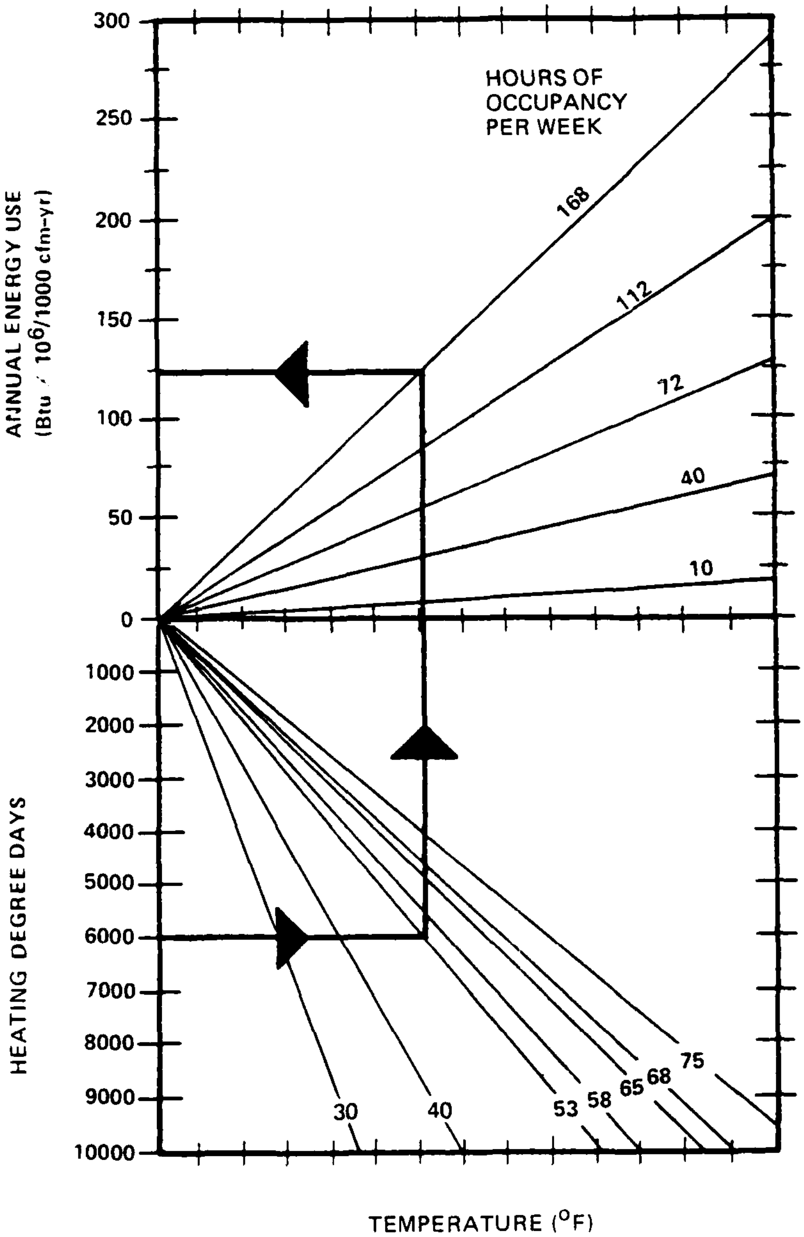
Instructions for use of nomograph 16:

1. Enter the nomograph on the lower left-hand vertical line at the heating degree days.

2. Proceed horizontally right to the temperature line.

3. Proceed vertically upward from this intersection to the number of hours of occupancy per week.

4. Proceed horizontally left from this intersection to determine the annual energy used in Btu x 10^6 per year per 1,000 cfm.



Nomograph 16. Heating - Annual Energy Used Per 1,000 cfm Outside Air

Nomograph 17 Engineering Data

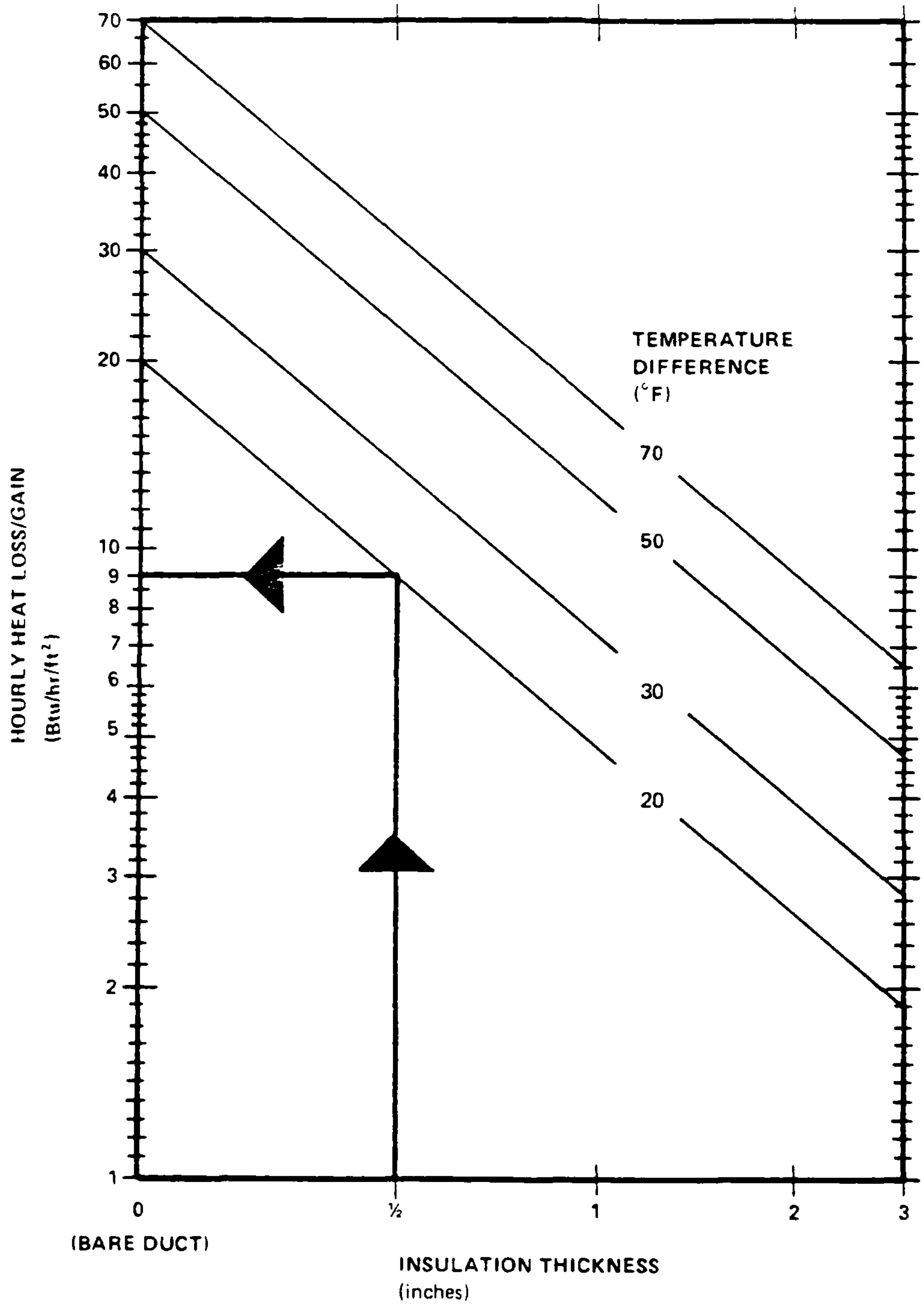
Source of Data: ASHRAE Handbook of Fundamentals
(Assumes rigid insulation with K-value of 0.27 at 75°F).

Instructions for use of nomograph 17:

1. Enter the nomograph on the lower horizontal line at the existing thickness of duct insulation.

2. Proceed vertically upward to the line that most closely fits the temperature difference between the air inside the duct and air outside the duct.

3. Proceed horizontally left from this intersection to read the heat loss or gain in Btu per hour per square feet.



Nomograph 17. Duct Insulation - Heat Loss/Gain for Various Thicknesses

Nomograph 18 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

The nomograph assumes the addition of insulation with a thermal conductivity ($K = 0.3$ Btu-in/ft^2-hr-^{o}F) and ambient air temperature of 68^{o}F.

Instructions for use of nomograph 18:

1. Enter the nomograph on the lower vertical line at the pipe size in inches.

2. Proceed horizontally right to the curve that most closely fits thickness of insulation.

3. Proceed vertically upward from this intersection to the operating water temperature line.

4. Proceed horizontally left to read the heat loss in Btu per hour per 10-foot pipe length.

TO CALCULATE ENERGY SAVINGS FOR CASES WHICH DO NOT MATCH THE NOMOGRAPH 18 ASSUMPTIONS:

Determine heat loss per square foot of pipe insulation by using the following equation:

$$U_2 = \frac{1}{\dfrac{r_2 \ln (r_2/r_1)}{k}} + \frac{1}{f}$$

where:

U_2 = Heat Loss Per Hour Per Degree Difference in Temperature, Per Square Foot of Outer Surface of Pipe Insulation

r_1 = External Radius of the Pipe

r_2 = the Radius of the Outer Surface of the Insulation

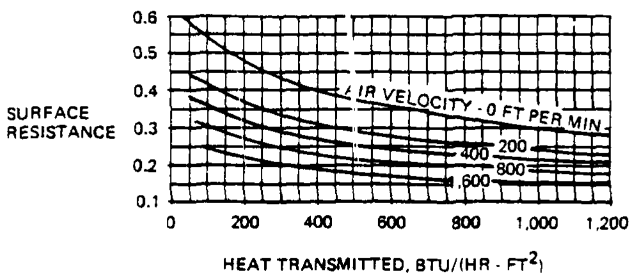
ln = Natural Logarithm (base e)

k = Thermal Conductivity of the Insulation (Btu-in/(hr-^{o}F-ft^2) from Table 2

$\frac{1}{f}$ = Surface Resistance (ft^2 hr/Btu)

Two iterations are required. First, the value of U_2 is calculated by neglecting the $1/f$ term in order to obtain the conducted heat transfer at the outer surface of the planned insulation.

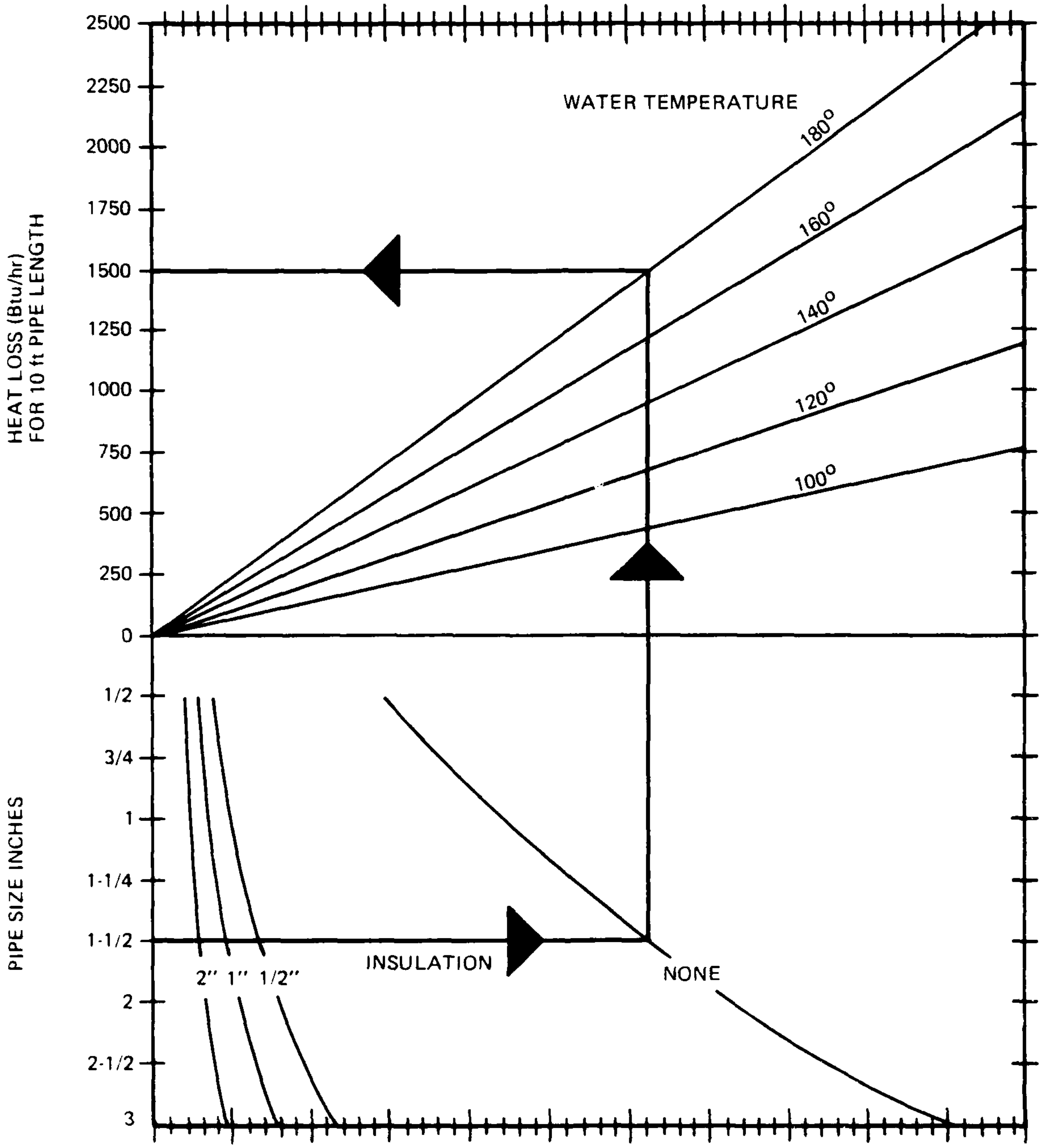
This value of transmitted heat is used to enter the figure below to obtain the surface resistance value to use in the second iteration which takes heat transfer by convection into account for various amounts of air flow over the insulated surface.



SURFACE RESISTANCE 1/F AT VARIOUS AIR VELOCITIES.

In the second iteration, U_2 is calculated, using the value of $1/f$ obtained from the figure.

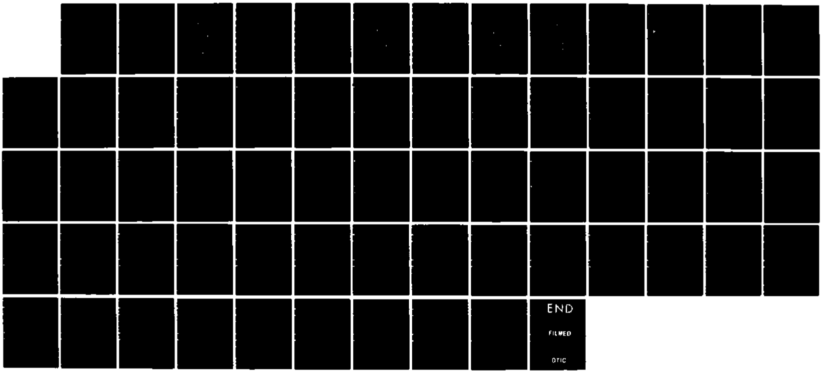
The total annual heat loss is obtained by multiplying the new value of U_2 by the number of square feet of pipe surface, by the temperature difference between the interior of the pipe and the ambient temperature, and by the number of operating hours per year; and then by dividing the resulting product by the plant efficiency (site specific data or for typical values see Supporting Data, SD 2-4: HEFF).

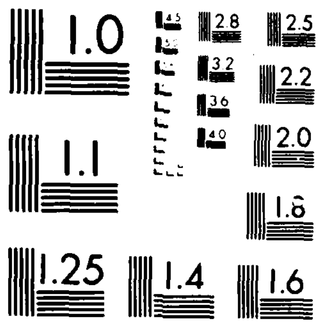


Nomograph 18. Heating - Heat Loss for Various Pipe Sizes, Insulation Thickness, and Water Temperatures from 100 to 180°F

AD-A163 295 NAVY ACTIVITY-LEVEL ENERGY SYSTEMS PLANNING PROCEDURE 4/4
(A-LESP) USERS MANUAL(U) DEPARTMENT OF THE NAVY
WASHINGTON DC 1986

UNCLASSIFIED F/G 13/1 NL





MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

Nomograph 19 Engineering Data

Source of Data: <u>Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)</u>

The nomograph is based on the addition of insulation with a thermal conductivity of 0.3 ($k = 0.3$ Btu-in/ft^2-hr-$^\circ$F) based on an ambient air temperature of 68°F.

The following formula is the basis for determining the heat emitted (heat loss from the pipe):

$$q = \frac{T_s - T_a}{\frac{d_1}{2k}\left(\log_e \frac{d_2}{d_1}\right) + \frac{d_1}{fd_2}}$$

where:

q = Heat Emission from Insulated Hot Pipe in Btu/ft^2-hr

T_s = Temperature of Pipe Surface in $^\circ$F

T_a = Ambient Air Temperature in $^\circ$F

d_1 = Outside Diameter of Pipe in inches

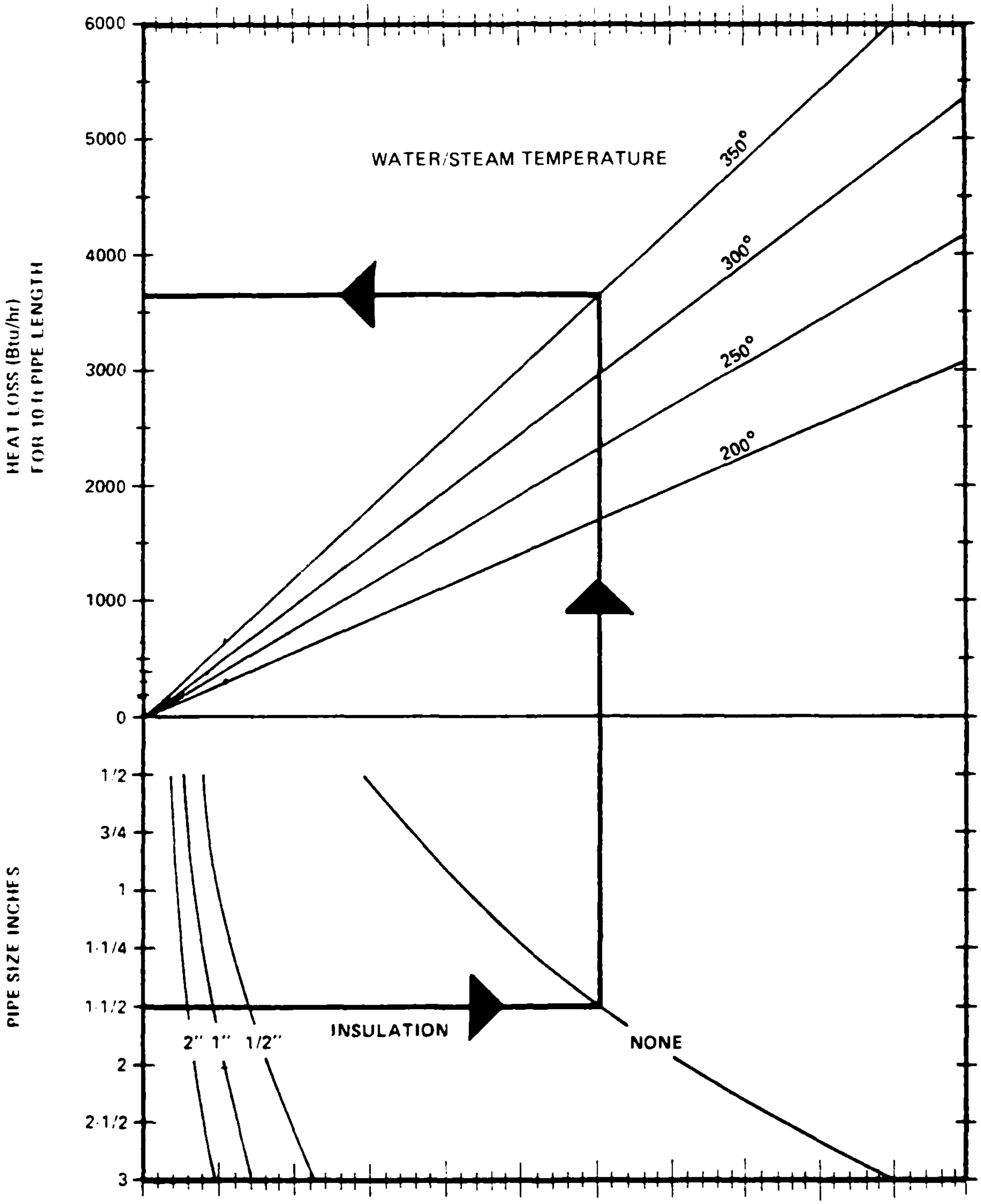
d_2 = Outside Diameter of Insulation in inches

k = Thermal Conductivity of Insulating Material in Btu-in/ft^2-hr-$^\circ$F (table 2)

f = Surface Coefficient in Btu/ft^2-hr-$^\circ$F

Instructions for use of nomograph 19:

1. Enter the nomograph on the lower vertical line at the pipe size in inches.
2. Proceed horizontally right to the curve that most closely fits the thickness of the insulation.
3. Proceed vertically upward from this intersection to the operating water/steam temperature line.
4. Proceed horizontally left from this intersection to read the heat loss in Btu per hour per 10 feet of pipe length.



Nomograph 19. Heating - Heat Loss for Various Pipe Sizes, Insulation Thickness, and Water/Steam Temperatures from 200 to 350°F

Nomograph 20 Engineering Data

Source of Data: Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

The nomograph is based on the addition of insulation with a thermal conductivity of 0.3 ($k = 0.3 \times$ Btu-in/ft^2-hr-^{o}F) based on an ambient air temperature of 68^{o}F.)

The following formula is the basis for determining the heat emitted (heat loss from the pipe):

$$q = \frac{T_s - T_a}{\frac{d_1}{2k}\left(\log_e \frac{d_2}{d_1}\right) + \frac{d_1}{fd_2}}$$

where:

q = Heat Emission from Insulated Hot Pipe in Btu/ft^2-hr

T_s = Temperature of Pipe Surface in ^{o}F

T_a = Ambient Air Temperature in ^{o}F

d_1 = Outside Diameter of Pipe in inches

d_2 = Outside Diameter of Insulation in inches

k = Thermal Conductivity of Insulating Material in Btu-in/ft^2-hr-^{o}F (table 2)

f = Surface Coefficient in Btu/ft^2-hr-^{o}F

Instructions for use of nomograph 20:

1. Enter the nomograph on the lower horizontal line at the pipe size in inches.
2. Proceed vertically upward to the curve that most closely fits the thickness of the existing insulation.
3. Proceed horizontally left from this intersection to read the heat gain in Btu per hour per 10 feet of pipe length.

Nomograph 21 Engineering Data

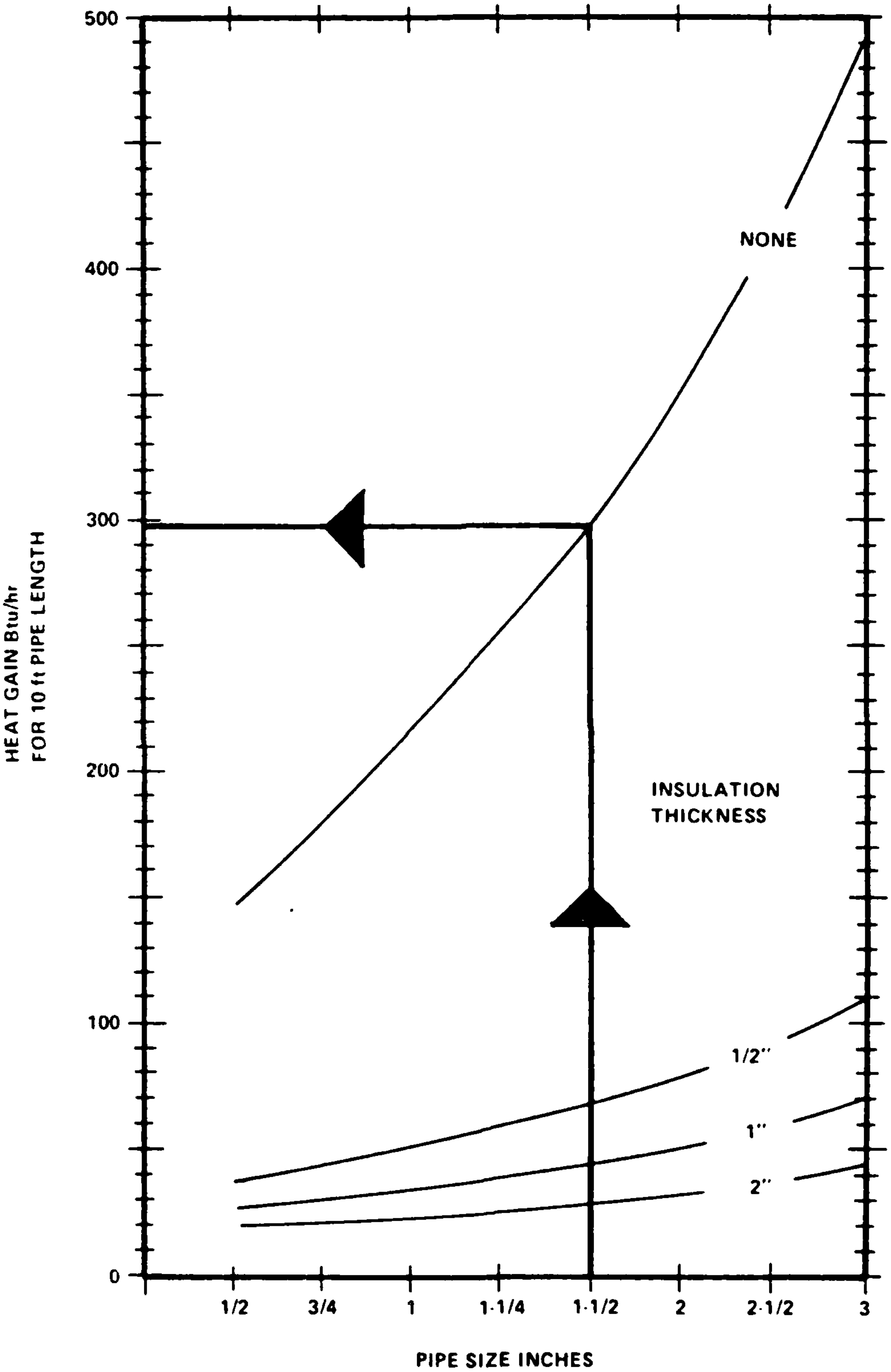
Source of Data: Manufacturer's Data

Instructions for use of nomograph 21:

1. Enter the nomograph on the lower horizontal line at the malfunctioning steam trap orifice size.

2. Proceed vertically upward to the line that most closely fits the operating steam pressure.

3. Proceed horizontally left from this intersection to read the steam loss in pounds per hour.



Nomograph 20. Cooling - Heat Gain for Various Pipe Sizes and Insulation Thickness 45°F Water

Nomograph 22 Engineering Data

Source of Data: Data from various boiler and burner manufacturers was analyzed and integrated to make up one graph.

Instructions for use of nomograph 22:

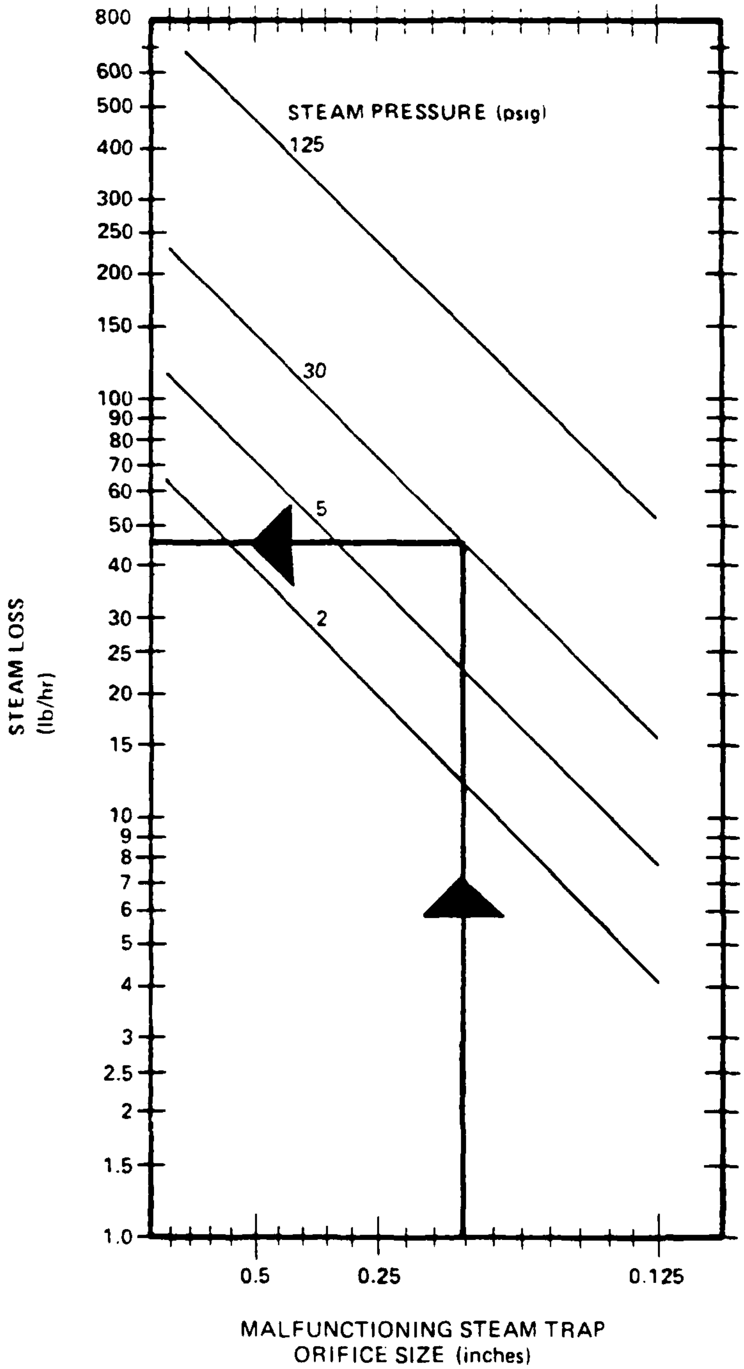
1. Enter the nomograph at the lower horizontal line at the percentage of CO_2 in the flue gas for the fuel being used.

- OR -

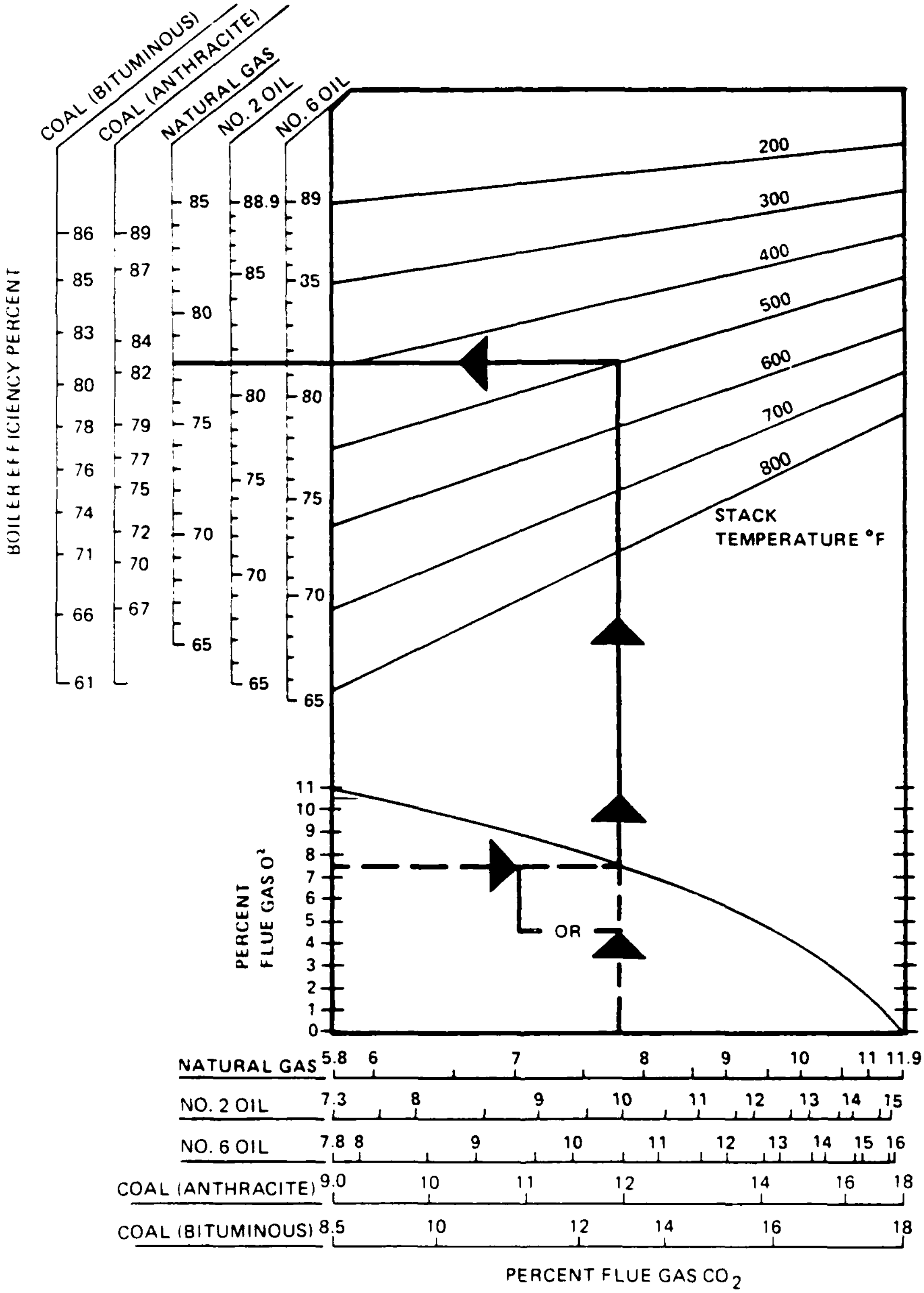
Enter the lower left-hand vertical pa t of the nomograph at the percentage O_2 in the flue gas and proceed horizontally right to the intersection of the plotted curved line.

2. Proceed vertically upward at this intersection to the stack temperature line.

3. Proceed horizontally left at this intersection and read the boiler efficiency corresponding to the fuel used.



Nomograph 21. Steam Traps - Steam Loss Through Leaking Steam Traps



Nomograph 22. Heating - Effect on Flue Gas Composition and Temperature on Boiler Efficiency

Nomograph 23 Engineering Data

Source of Data: Standardized Energy Calculations for Energy Monitoring and Control Systems (EMCS)

Instructions for use of Nomograph 23:

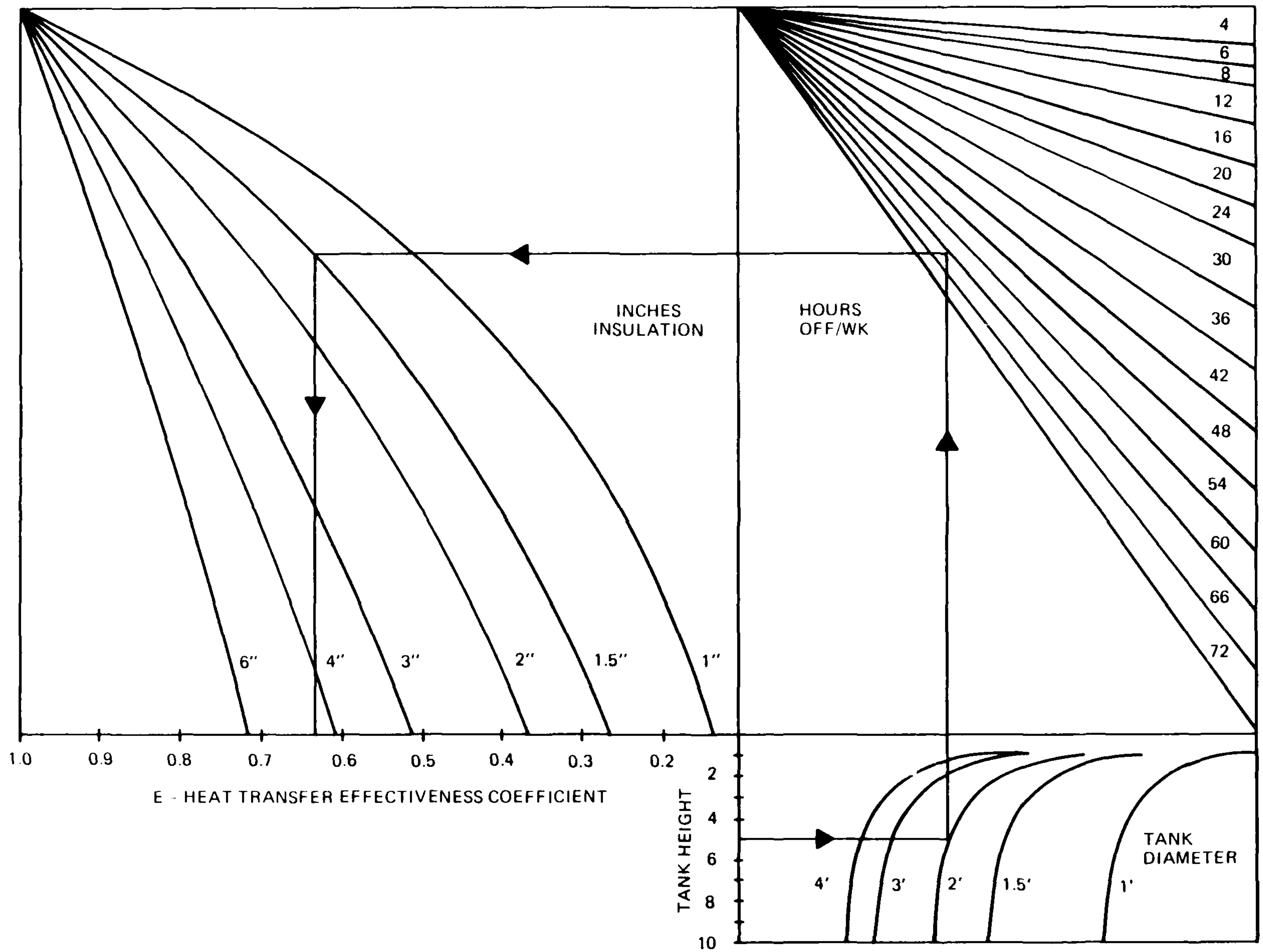
1. Enter the nomograph at the lower horizontal line at the hotwater tank height.

2. Proceed horizontally right to the curve that most closely fits the tank diameter.

3. Proceed vertically upward from this intersection to the hours off/wk line.

4. Proceed horizontally left to the curve that most closely fits the inches of insulation.

5. Proceed vertically downward from this intersection to read E, the heat transfer effectiveness coefficient.



Nomograph 23. Heat Transfer Effectiveness Coefficient (E)

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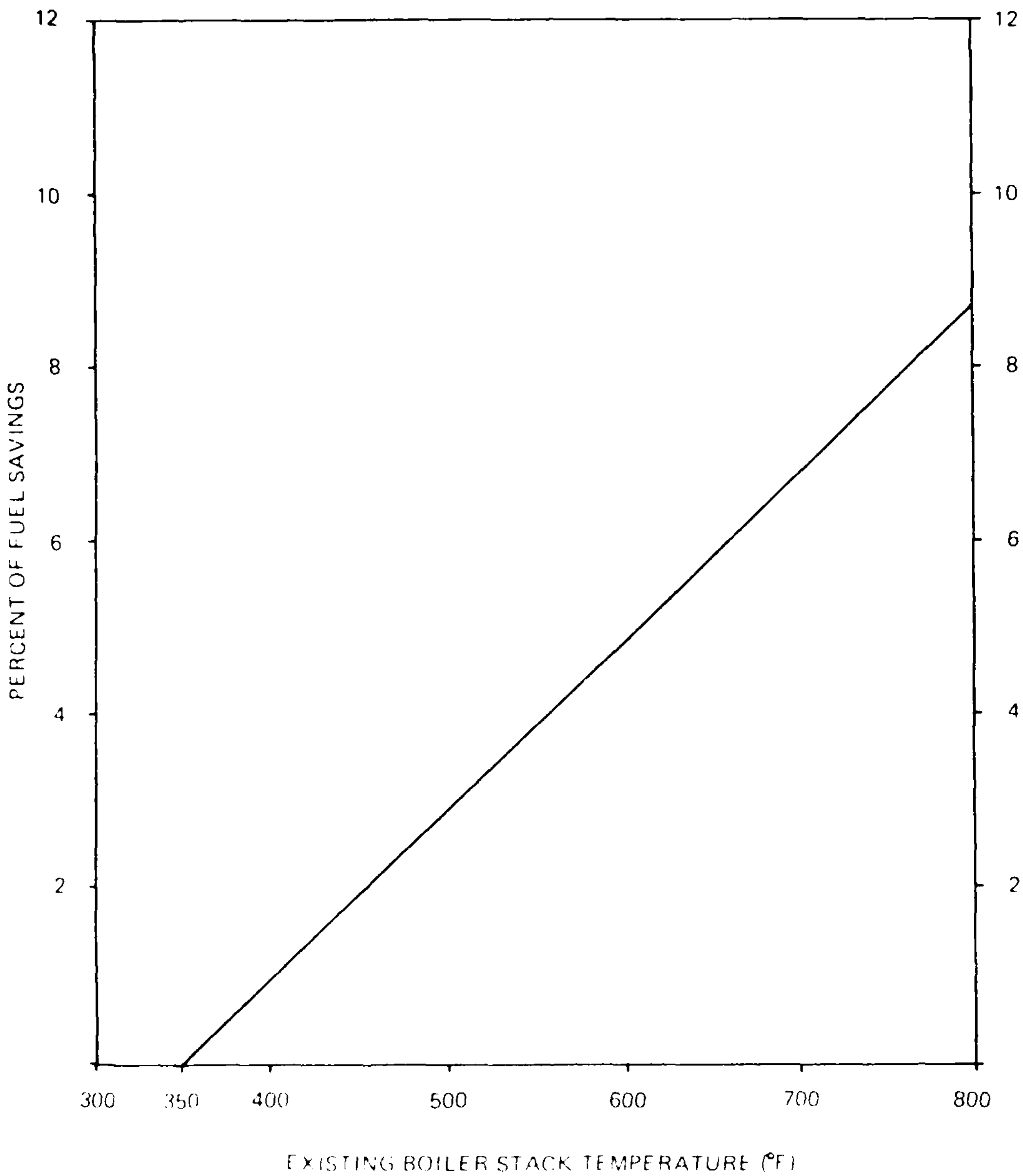

Figure 1. Potential Percent of Fuel Savings Through Economizer Use

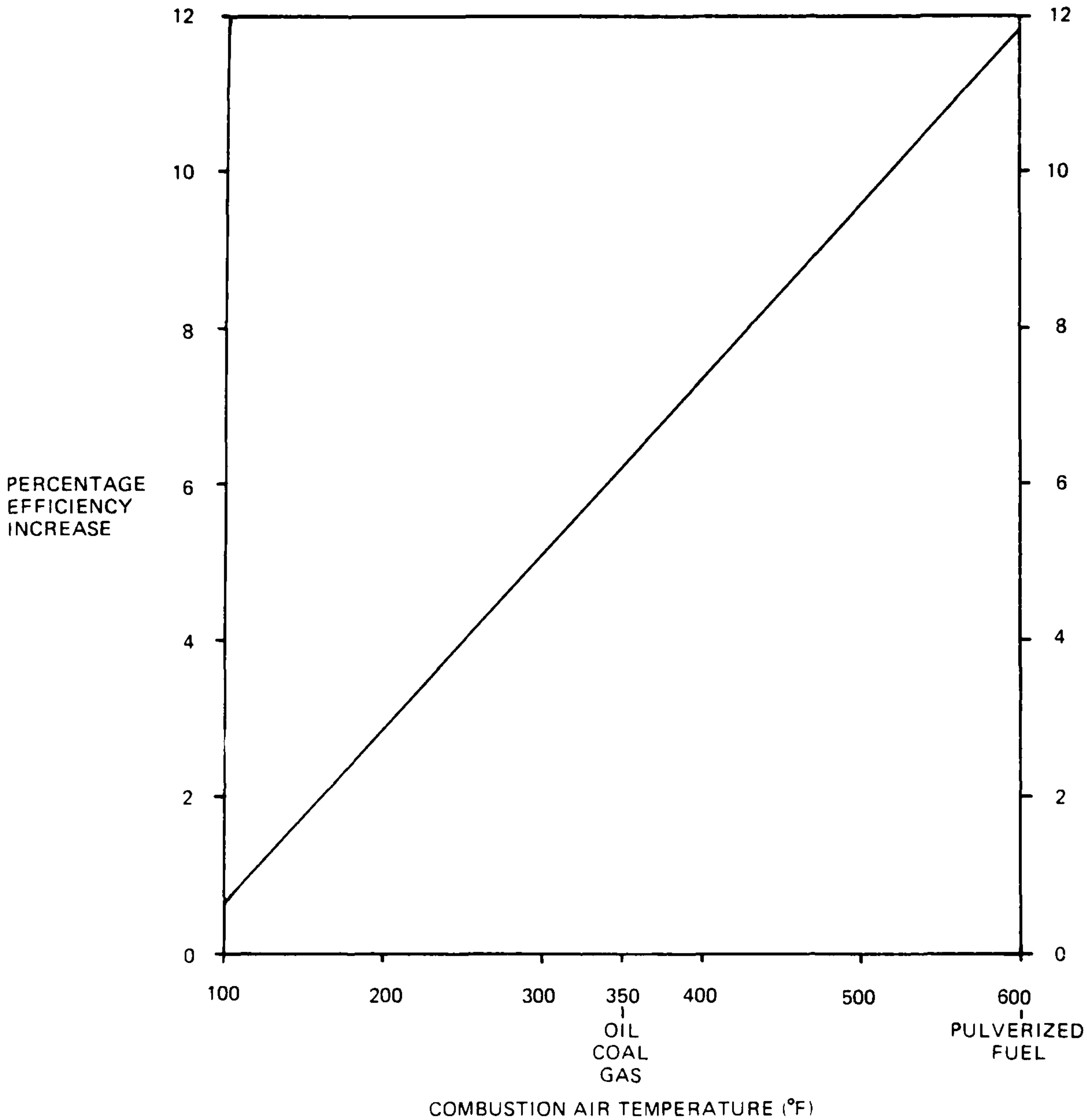

Figure 2. Efficiency Increase with Preheated Air

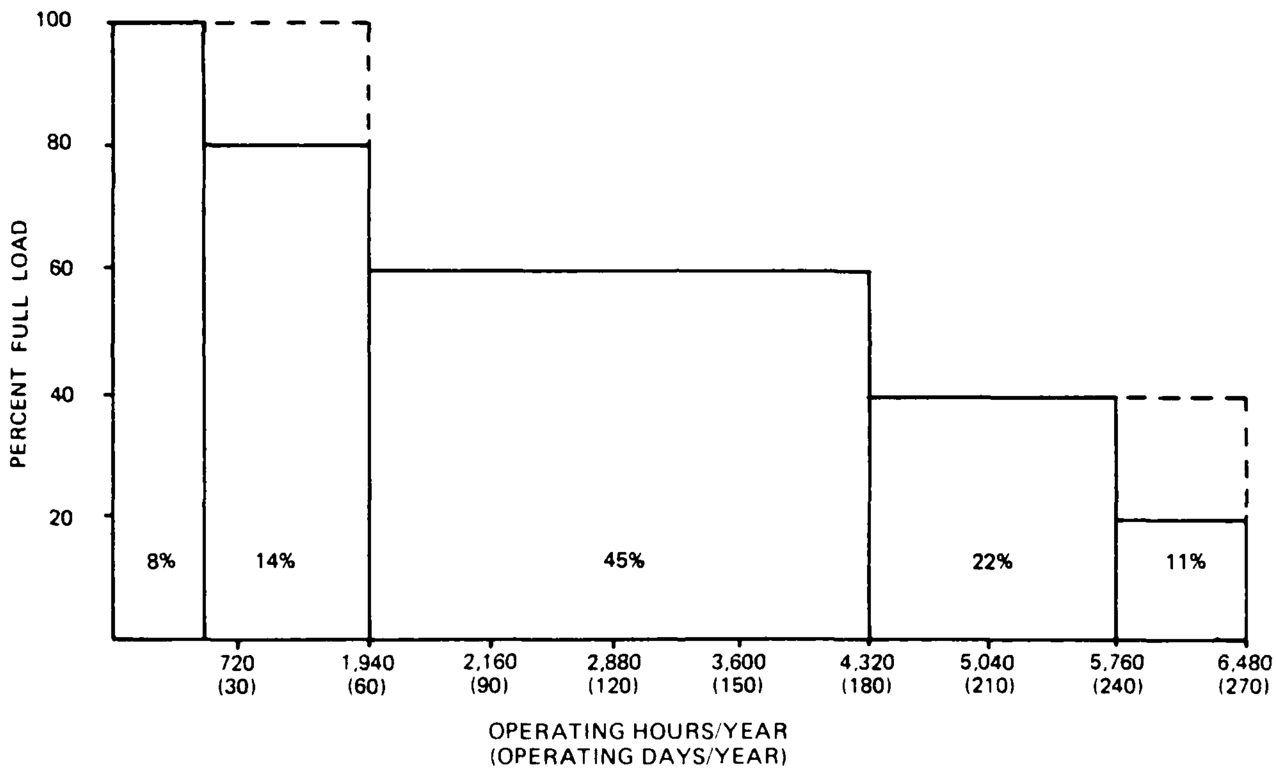

Figure 3. Percent Full Load

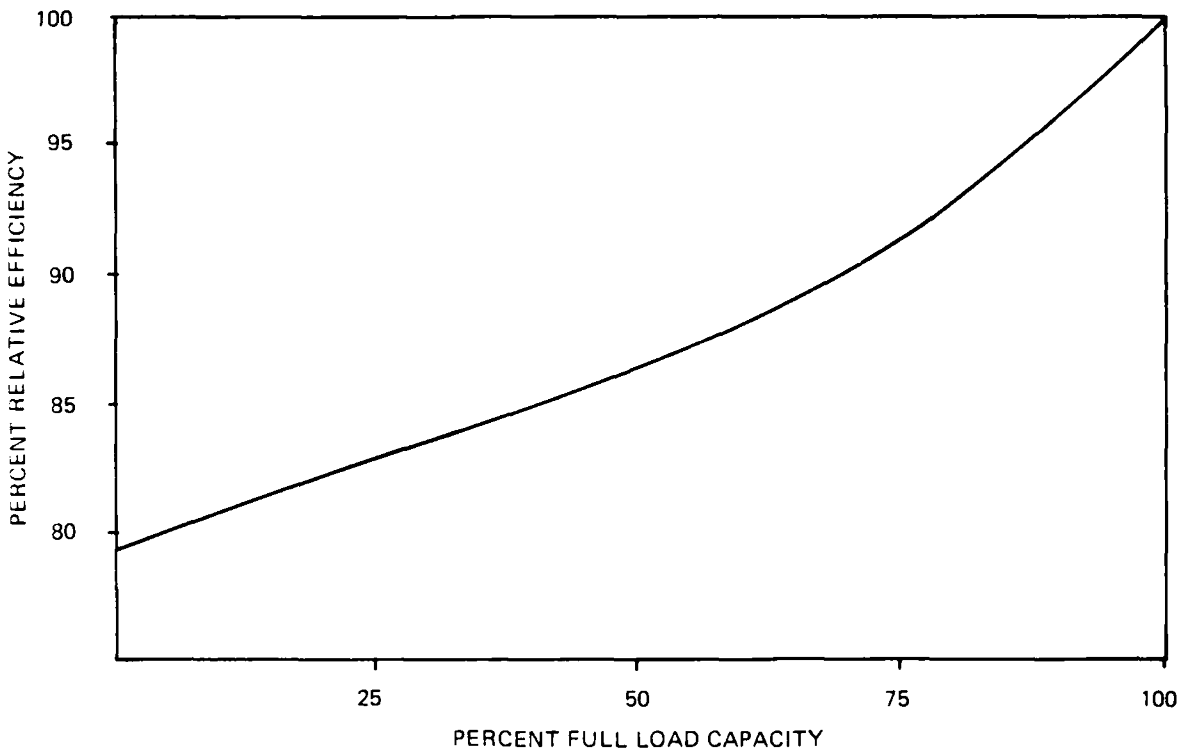

Figure 4. Percent Relative Efficiency

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Table 1. R and U-Values for Common Walls, Roofs, Floors, and Windows

Description	R (ft^2-^oF-hr/Btu)	U-Value (Btu/(ft^2-^oF-hr))
WALLS		
1-in. stucco, air space, 3-in. insulation	12.05	0.083
Metal siding, 3-in. insulation, air space metal	11.63	0.086
Surface finish, 3-in. insulation, surface finish	11.11	0.09
4-in. face brick, 2-in. insulation, 8-in. concrete block	10	0.1
Expanded polyurethane (1-in.)	6.25	0.16
Expanded polystyrene extruded (1-in.)	5.26	0.19
1-in. stucco, 8-in. concrete, 1-in. insulation	5.05	0.198
Metal siding, 1-in. insulation, air space, metal	4.93	0.203
4-in. face brick, air space, 8-in. concrete block	4.22	0.237
4-in. lightweight concrete	4.17	0.24
4-in. face brick, air space, 4-in. common brick	2.99	0.335
1-in. vermiculite exfoliated	2.13	0.47
1-in. stucco, air space	1.95	0.512
0.5-in. gypsum or plasterboard	0.56	1.78
Insulating drapes	1.72	0.58
ROOFS		
2-in. insulation, 1-in. wood, air space, acoustic ceiling	11.77	0.085
2-in. insulation, metal deck, air space, acoustic ceiling	10.53	0.095
2-in. insulation, 2 in. wood	8.93	0.112
1-in. insulation, 1-in. wood, air space, acoustic ceiling	8.3	0.12
2-in. insulation, 4-in. heavy weight concrete	8.07	0.124
2-in. insulation, metal deck	7.75	0.129
1-in. insulation, metal deck, air space, acoustic ceiling	7.14	0.14
4-in. lightweight concrete, air space, acoustic ceiling	7.14	0.14
1-in. insulation, 1-in. wood	5.56	0.18
FLOORS		
0.5-in. plywood (douglas fir)	0.62	1.61
Tile and lay-in panels, 0.5-in. plain or acoustic	1.25	0.8
3/4-in. wood subfloor	0.94	1.06
Carpet and fiberous pad	2.08	0.48
3/4-in. wood, hardwood finish	0.68	1.47
Sound deadening board, 0.5-in.	1.35	0.74
WINDOW DATA		
Flat glass, single glass	0.94	1.07
Insulating glass - double, 0.25-in. air space	1.69	0.59
Insulating glass - double, 0.5-in. air space	1.89	0.53
Storm windows, 1-in. to 4-in. air space	2.0	0.5
Insulating glass - triple, 0.25-in. air space	2.4	0.41
Insulating glass - triple, 0.5-in. air space	2.9	0.35

Table 2. Thermal Conductivity (k) of Industrial Insulation (Design Values)*

Form/Material Composition	Accepted Max Temp for Use, °F**	Typical Density (lb/ft^3)	Typical Conductivity (k) at Mean Temp °F												
			-100	-75	-50	-25	+0	+25	+50	+75	+100	+200	+300	+500	+700
BLOCKS, BOARDS & PIPE INSULATION															
ASBESTOS															
Laminated asbestos paper	700	30									0.40	0.45	0.50	0.60	
Corrugated & laminated asbestos															
Paper															
4-ply	300	11-13								0.54	0.57	0.68			
6-ply	300	15-17								0.49	0.51	0.59			
8-ply	300	18-20								0.47	0.49	0.57			
MOLDED AMOSITE & BINDER	1500	15-18									0.32	0.37	0.42	0.52	0.62
85% MAGNESIA	600	11-12									0.35	0.38	0.42		
CALCIUM SILICATE	1200	11-13									0.38	0.41	0.44	0.52	0.62
	1800	12-15												0.63	0.74
CELLULAR GLASS	800	9			0.32	0.33	0.35	0.36	0.38	0.40	0.42	0.48	0.55		
DIATOMACEOUS SILICA	1600	21-22												0.64	0.68
	1900	23-25												0.70	0.75
MINERAL FIBER															
Glass,															
Organic bonded, block and boards	400	3-10	0.16	0.17	0.18	0.19	0.20	0.22	0.24	0.25	0.26	0.33	0.40		
Nonpunking binder	1000	3-10									0.26	0.31	0.38	0.52	
Pipe insulation, slag or glass	350	3-4					0.20	0.21	0.22	0.23	0.24	0.29			
	500	3-10					0.20	0.22	0.24	0.25	0.26	0.33	0.40		
Inorganic bonded-block	1000	10-15									0.33	0.38	0.45	0.55	
	1800	15-24									0.32	0.37	0.42	0.52	0.62
Pipe insulation slag or glass	1000	10-15									0.33	0.38	0.45	0.55	
MINERAL FIBER															
Resin binder		15			0.23	0.24	0.25	0.26	0.28	0.29					
RIGID POLYSTYRENE															
Extruded, Refrigerant 12 exp	170	3.5	0.16	0.16	0.15	0.16	0.16	0.17	0.18	0.19	0.20				
Extruded, Refrigerant 12 exp	170	2.2	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.20					
Extruded	170	1.8	0.17	0.18	0.19	0.20	0.21	0.23	0.24	0.25	0.27				
Molded beads	170	1	0.18	0.20	0.21	0.23	0.24	0.25	0.26	0.28					
POLYURETHANE***															
Refrigerant 11 exp	210	1.5-2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16	0.17				
RUBBER, Rigid Foamed	150	4.5						0.20	0.21	0.22	0.23				
VEGETABLE & ANIMAL FIBER															
Wool felt (pipe insulation)	180	20						0.28	0.30	0.31	0.33				
INSULATING CEMENTS															
MINERAL FIBER															
(Rock, slag, or glass)															
With colloidal clay binder	1800	24-30									0.49	0.55	0.61	0.73	0.85
With hydraulic setting binder	1200	30-40									0.75	0.80	0.85	0.95	
LOOSE FILL															
Cellulose insulation (milled pulverized paper or wood pulp)		2.5-3							0.26	0.27	0.29				
Mineral fiber, slag, rock or glass		2-5			0.19	0.21	0.23	0.25	0.26	0.28	0.31				
Perlite (expanded)		5-8	0.25	0.27	0.29	0.30	0.32	0.34	0.35	0.37	0.39				
Silica aerogel		7.6			0.13	0.14	0.15	0.15	0.16	0.17	0.18				
Vermiculite (expanded)		7-8.2			0.39	0.40	0.42	0.44	0.45	0.47	0.49				
		4-6			0.34	0.35	0.38	0.40	0.42	0.44	0.46				

* Representative values for dry materials as selected by ASHRAE TC 4.4, Installation and Moisture Barriers, and expressed in Btu per hr-ft^2-°F per inch. They are intended as design (not specification) values for materials of building construction for normal use. For thermal resistance of a particular product, use the value supplied by the manufacturer or by unbiased tests.

** These temperatures are generally accepted as maximum. When operating temperature approaches these limits, follow the manufacturer's recommendations.

***Values are for aged board stock. For change in conductivity with age of refrigerant-blown expanded urethane, refer to ASHRAE Fundamentals Handbook.

Note: Some polyurethane foams are formed by means which produce a stable product (with respect to k), but most are blown with refrigerant and will change with time.

$$\text{U-Value} = \frac{\text{K-Value}}{\text{Insulation Thickness (inches)}}$$

Table 3. U-Values for Glazing with Insulating Drapes

Solar Transmission Value (U-Value-Winter*)	Single** Glaze	Double Glaze	Triple Glaze
Nominal U-value	1.15	0.55	0.35
Average U-value with R-4 insulating drape in place 24 hr/day	0.21	0.17	0.14
Average U-value with R-4 drape in place 16 hr/day	0.45	0.27	0.20
Average U-value with R-4 drape in place 12 hr/day	0.52	0.29	0.21
Average U-value with R-10 insulating drape in place 24 hr/day	0.90	0.085	0.078
Average U-value with R-10 drape in place 16 hr/day	0.36	0.20	0.15
Average U-value with R-10 drape in place 12 hr/day	0.44	0.24	0.17

* Values are slightly different in summer.
**For 1/8-inch grade B window glass only.

Table 4A. Shading Coefficients Without Shading Device

Glass	Coefficient
1/8-in. Clear Double Strength	1.00
1/4-in. Clear Glass (single glaze)	0.93 - 0.95
1/4-in. Heat Absorbing Plate	0.65 - 0.70
1/4-in. Reflective Plate	0.23 - 0.56
1/4-in. Laminated Reflective	0.28 - 0.42
1-in. Clear Insulating Glass (double glaze)	0.80 - 0.83
1-in. Heat Absorbing Insulating Plate	0.43 - 0.45
1-in. Reflective Insulating Plate	0.13 - 0.31

Table 4B. Shading Coefficients with Shading Device

Shading Device	Coefficient With 1/4-in. Clear Plate Glass (single glaze)	Coefficient With 1-in. Clear Insulating Glass (double glaze)
Venetian Blinds - light colored, fully closed	0.55	0.51
Roller Shade - light colored, translucent, fully drawn	0.39	0.37
Drapes - semi-open weave, average fabric transmittance and reflectance, fully closed	0.55	0.48
Reflective Polyester Film	0.24	0.20
Overhang	0.40	0.30
Louvered Sun Screens		
- 23 louvers/in.	0.15 - 0.35	0.10 - 0.29
- 17 louvers/in.	0.18 - 0.51	0.12 - 0.45

Table 4C. Estimated Solar Control Device Costs

Solar Control Device	Average Installed Cost* Per Square Foot
External Louvered Screens	$13.00
Tinted or Reflective Glass	10.00
Reflective Polyester Film	4.00
Venetian Blinds	5.00
Vertical Louvered Blinds	6.00
Roller Shades	5.25
Thermal Drapes	4.39

*Edited to reflect 1983 costs.

Table 5. Solar Absorption Coefficients

Typical Building Materials	Coefficient
Tinned Surface	0.05
White Glazed Brick	0.25
White on Galvanized Iron	0.26
White Gravel	0.29
Bituminous Felt-Aluminized	0.40
Aluminum Paint	0.40
White Built-up Roof	0.50
Light Buff Brick	0.55
White Marble	0.58
White Asbestos Cement	0.61
Uncolored Concrete	0.65
Uncolored Asbestos Cement	0.75
Wood, Smooth	0.78
Asphalt Pavement, Weathered	0.82
Green Roofing	0.86
Blue Gray Slate	0.87
Red Brick	0.88
Bituminous Felt	0.88

Table 6. Air Leakage Between Door and Frame

Expressed in Cubic Feet Per Minute (cfm)

Type of Door	Pressure Difference (inches of water)[1]		
	0.1	0.2	0.3
Nonweatherstripped[2]			
1. Poorly fitted	2.6	4.0	5.0
2. Well fitted	1.3	2.0	2.5
Weatherstripped[2]			
1. Poorly fitted	1.3	2.0	2.5
2. Well fitted	0.7	1.0	1.3

Table 6A. Infiltration Through Double Hung Wood Windows

Expressed in Cubic Feet Per Minute (cfm)

Type of Window	Pressure Difference (inches of water)		
Frame-Wall Leakage[3, 4]	0.1	0.2	0.3
1. Around frame in masonry wall, not caulked	0.28	0.43	0.56
2. Around frame in masonry wall, caulked	0.05	0.08	0.1
3. Around frame in wood frame wall	0.22	0.35	0.48

1. Values were determined using ASHRAE Fundamentals Handbook, 1981, chapter 22 "Air Leakage Through Exterior Doors.

2. Typical Pressure Differences for various facilities:
   Data Processing/Special Application Facility = 0.3
   Single or Multistory (forced air/HVAC forced air) = 0.2
   Single Story (forced air) = 0.2
   Non-forced air facility = 0.1

3. Leakage is that passing between the frame of a double-hung window and the wall.

4. The values given for frame leakage are foot of sash perimeter, as determined for double-hung wood windows. Some of the frame leakage in masonry walls originates in the thick wall itself, and cannot be prevented by caulking. For the additional reason that caulking is not done perfectly and deteriorates with time, it is considered advisable to choose the masonry frame leakage values for caulked frames as the average determined by the caulked and noncaulked tests.

Table 7. Costs for Insulating Various Pipe Sizes

	Installed Cost/Linear Foot of Pipe Insulation*	
Pipe Size (Inches)	1 Inch Thickness (Fibrous Material)	2 Inch Thickness (Fibrous Material)
1/2	$3.05	$6.35
3/4	3.20	6.50
1	3.30	6.80
1-1/4	3.50	7.00
1-1/2	3.75	7.35
2	3.95	7.65
2-1/2	4.25	8.10
3	4.50	8.55
3-1/2	5.00	9.00
4	5.40	9.65
5	5.90	10.50
6	6.40	11.10
8	8.60	13.50
10	10.20	16.05
12	11.90	18.00

*These are average installation costs, including labor and material, for pipe located in accessible areas. Inaccessibility would increase the costs.

Source: Mechanical and Electrical Cost Data 1983, R.S. MEANS Co. Inc.

Table 7A. Costs for Insulating Various Ductwork Sizes

Installed Cost/Square Foot of Duct Insulation		
Insulation Thickness (inches)	3/4-lb Density Fiberous Glass Blanket, with Reinforced Foil, Kraft Facing Lapped, Joints Sealed	Rigid Fiberous Glass Board with Foil Facing Vapor Seal and Attached to Ducts or Housings with Mechanical Fasteners
1	$ .99	$5.50
1-1/2	$1.30	$5.84
2	$1.46	$6.84

Source: Richardson Engineering Services, Inc.

Table 8. Recommended Lighting Levels

Type of Activity	Ranges of Illuminances*			
	Illuminance Category	Lux	Footcandles	Reference Work-Plane
Public spaces with dark surroundings	A	20-30-50	2-3-5	
Sample orientation for short temporary visits	B	50-75-100	5-7.5-10	General lighting throughout spaces
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20	
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50	
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100	Illuminance on task
Performance of visual tasks of low contrast or very small size	F	1000-1500-2000	100-150-200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	200-300-500	
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000	Illuminance on task. Obtained by a combination of general and local (supplementary lighting)
Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000-20000	1000-1500-2000	

*With proper attention to quality, these levels should generally be adequate for the generic types of activities cited.

Consult latest IES <u>Lighting Handbook</u> (Applications Volume) for more specific guidance and/or guidance for other situations.

Table 9. Watts Saved by Lamp and Ballast Removal

Type of Fluorescent Lamp Removed	Watts Saved Per Lamp Removed	Watts Saved Per Ballast Disconnected
4-foot energy conserving (34 watt)	34	6
4-foot standard (F40CW)	40	6
4-foot high output	60	12
8-foot energy conserving	60	10
8-foot standard (F96T12)	75	10
8-foot energy conserving high output	90	12
8-foot high output	100	12

Table 10. Factor for Determining Heat Loss (F) for Various Types of Buildings

Building Type	Condition	Qualification	Loss Factor (F)-Btu/(°F-hr-ft^3)
Factories and Industrial Plants, General Office Areas (70°F)	One Story	Skylight in Roof	0.089
		No Skylight in Roof	0.081
	Multiple Story	Two Story	0.066
		Three Story	0.061
		Four Story	0.059
		Five Story	0.056
		Six Story	0.051
	All Walls Exposed	Flat Roof	0.099
		Heated Space Above	0.074
	One Long Warm Common Wall	Flat Roof	0.090
		Heated Space Above	0.067
	Warm Common Walls on Both Long Sides	Flat Roof	0.083
		Heated Space Above	0.059
Warehouses (60°F)	All Walls Exposed	Skylights in Roof	0.092
		No Skylights in Roof	0.085
		Heated Space Above	0.067
	One Long Warm Common Wall	Skylight in Roof	0.083
		No Skylight in Roof	0.082
		Heated Space Above	0.057
	Warm Common Walls on Both Long Sides	Skylight in Roof	0.078
		No Skylight in Roof	0.073

Note: This table tends to be conservative, particularly for new buildings designed for minimum energy consumption.

Table 11. Typical Luminaire Coefficients of Utilization* (CU)

Typical Luminaire	Pcc	80			70			50			30			10			0
	Pw	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0
	RCR	Coefficients of Utilization for 20 Percent Effective Floor Cavity Reflectance (Pfc = 20)															
Fluorescent unit with flat prismatic lens, two lamps, 1 ft wide	0	.69	.69	.69	.67	.67	.67	.64	.64	.64	.61	.61	.61	.59	.59	.59	.58
	1	.62	.60	.58	.61	.59	.57	.58	.57	.55	.56	.55	.54	.54	.53	.52	.51
	2	.55	.52	.49	.54	.51	.49	.52	.50	.48	.51	.48	.47	.49	.47	.46	.44
	3	.50	.46	.43	.49	.45	.42	.47	.44	.41	.46	.43	.41	.44	.42	.40	.39
	4	.45	.40	.37	.44	.40	.37	.43	.39	.36	.41	.38	.36	.40	.37	.35	.34
	5	.40	.35	.32	.39	.35	.32	.38	.34	.31	.37	.34	.31	.36	.33	.31	.30
	6	.36	.31	.28	.36	.31	.28	.35	.31	.28	.34	.30	.27	.33	.30	.27	.26
	7	.33	.28	.25	.32	.28	.24	.31	.27	.24	.30	.27	.24	.30	.26	.24	.23
	8	.29	.25	.21	.29	.24	.21	.28	.24	.21	.27	.24	.21	.27	.23	.21	.20
	9	.26	.22	.18	.26	.21	.18	.25	.21	.18	.25	.21	.18	.24	.21	.18	.17
	10	.24	.19	.16	.24	.19	.16	.23	.19	.16	.22	.19	.16	.22	.19	.16	.15
Fluorescent unit with flat prismatic lens, four lamps, 2 ft wide - multiply by 1.10 for two lamps	0	.73	.73	.73	.72	.72	.72	.68	.68	.68	.66	.66	.66	.63	.63	.63	.62
	1	.66	.64	.62	.65	.63	.61	.62	.60	.59	.60	.58	.57	.57	.56	.55	.54
	2	.59	.55	.52	.58	.54	.52	.56	.53	.50	.54	.51	.49	.52	.50	.48	.47
	3	.53	.48	.45	.52	.48	.44	.50	.46	.44	.48	.45	.43	.47	.44	.42	.41
	4	.47	.42	.39	.46	.42	.38	.45	.41	.38	.43	.40	.37	.42	.39	.37	.36
	5	.42	.37	.33	.41	.37	.33	.40	.36	.33	.39	.35	.32	.38	.35	.32	.31
	6	.38	.33	.29	.37	.32	.29	.36	.32	.29	.35	.31	.28	.34	.31	.28	.27
	7	.34	.29	.25	.33	.29	.25	.33	.28	.25	.32	.28	.25	.31	.27	.25	.23
	8	.30	.25	.22	.30	.25	.22	.29	.25	.22	.28	.24	.21	.28	.24	.21	.20
	9	.27	.22	.19	.27	.22	.19	.26	.22	.19	.25	.21	.19	.25	.21	.18	.17
	10	.25	.20	.17	.24	.20	.16	.24	.19	.16	.23	.19	.16	.23	.19	.16	.15

Where:

Pcc = Ceiling Cavity Reflectance (Typical values: bright white: 80, dull white: 50)
* Pfc = Floor Cavity Reflectance (Typical value: bright color: 80, light colored: 10)
Pw = Wall Reflectance (Typical value: color wall: 50, light colored wall 10)
RCR = Room Cavity Ratio (see table 11A)
* See IES Handbook

Table 11A. Room Cavity Ratio

Room Dimensions		Cavity Depth[1]																			
Width	Length	1	1.5	2	2.5	3	3.5	4	5	6	7	8	9	10	11	12	14	16	20	25	30
8	8	1.2	1.9	2.5	3.1	3.7	4.4	5.0	6.2	7.5	8.8	10.0	11.2	12.5	-	-	-	-	-	-	-
	10	1.1	1.7	2.2	2.8	3.4	3.9	4.5	5.6	6.7	7.9	9.0	10.1	11.3	12.4	-	-	-	-	-	-
	14	1.0	1.5	2.0	2.5	3.0	3.4	3.9	4.9	5.9	6.9	7.8	8.8	9.7	10.7	11.7	-	-	-	-	-
	20	0.9	1.3	1.7	2.2	2.6	3.1	3.5	4.4	5.2	6.1	7.0	7.9	8.8	9.6	10.5	12.2	-	-	-	-
	30	0.8	1.2	1.6	2.0	2.4	2.8	3.2	4.0	4.7	5.5	6.3	7.1	7.9	8.7	9.5	11.0	-	-	-	-
	40	0.7	1.1	1.5	1.9	2.3	2.6	3.0	3.7	4.5	5.3	5.9	6.5	7.4	8.1	8.8	10.3	11.8	-	-	-
10	10	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	-	-	-	-	-
	14	0.9	1.3	1.7	2.1	2.6	3.0	3.4	4.3	5.1	6.0	6.9	7.8	8.6	9.5	10.4	12.0	-	-	-	-
	20	0.7	1.1	1.5	1.9	2.3	2.6	3.0	3.7	4.5	5.3	6.0	6.8	7.5	8.3	9.0	10.5	12.0	-	-	-
	30	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.3	4.0	4.7	5.3	6.0	6.6	7.3	8.0	9.4	10.6	-	-	-
	40	0.6	0.9	1.2	1.6	1.9	2.2	2.5	3.1	3.7	4.4	5.0	5.6	6.2	6.9	7.5	8.7	10.0	12.5	-	-
	60	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.9	3.5	4.1	4.7	5.3	5.9	6.5	7.1	8.2	9.4	11.7	-	-
12	12	0.8	1.2	1.7	2.1	2.5	2.9	3.3	4.2	5.0	5.8	6.7	7.5	8.4	9.2	10.0	11.7	-	-	-	-
	16	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.6	4.4	5.1	5.8	6.5	7.2	8.0	8.7	10.2	11.6	-	-	-
	24	0.6	0.9	1.2	1.6	1.9	2.2	2.5	3.1	3.7	4.4	5.0	5.6	6.2	6.9	7.5	8.7	10.0	12.5	-	-
	36	0.6	0.8	1.1	1.4	1.7	1.9	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.0	6.6	7.8	8.8	11.0	-	-
	50	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.6	3.1	3.6	4.1	4.6	5.1	5.6	6.2	7.2	8.2	10.2	-	-
	70	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.4	2.9	3.4	3.9	4.4	4.9	5.4	5.8	6.8	7.8	9.7	12.2	-
14	14	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.6	4.3	5.0	5.7	6.4	7.1	7.8	8.5	10.0	11.4	-	-	-
	20	0.6	0.9	1.2	1.5	1.8	2.1	2.4	3.0	3.6	4.2	4.9	5.5	6.1	6.7	7.3	8.6	9.8	12.3	-	-
	30	0.5	0.8	1.0	1.3	1.6	1.8	2.1	2.6	3.1	3.7	4.2	4.7	5.2	5.8	6.3	7.3	8.4	10.5	-	-
	42	0.5	0.7	1.0	1.2	1.4	1.7	1.9	2.4	2.9	3.3	3.8	4.3	4.7	5.2	5.7	6.7	7.6	9.5	11.9	-
	60	0.4	0.7	0.9	1.1	1.3	1.5	1.8	2.2	2.6	3.1	3.5	3.9	4.4	4.8	5.2	6.1	7.0	8.8	10.9	-
	90	0.4	0.6	0.8	1.0	1.2	1.4	1.6	2.0	2.5	2.9	3.3	3.7	4.1	4.5	5.0	5.8	6.6	8.3	10.3	12.4
17	17	0.6	0.9	1.2	1.5	1.8	2.1	2.3	2.9	3.5	4.1	4.7	5.3	5.9	6.5	7.0	8.2	9.4	11.7	-	-
	25	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10.0	12.5	-
	35	0.4	0.7	0.9	1.1	1.3	1.5	1.7	2.2	2.6	3.1	3.5	3.9	4.4	4.8	5.2	6.1	7.0	8.7	10.9	-
	50	0.4	0.6	0.8	1.0	1.2	1.4	1.6	2.0	2.4	2.8	3.1	3.5	3.9	4.3	4.5	5.4	6.2	7.7	9.7	11.6
	80	0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.8	2.1	2.5	2.9	3.3	3.6	4.0	4.3	5.1	5.8	7.2	9.0	10.9
	120	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.7	2.0	2.3	2.7	3.0	3.4	3.7	4.0	4.7	5.4	6.7	8.4	10.1
20	20	0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10.0	12.5	-
	30	0.4	0.6	0.8	1.0	1.2	1.5	1.7	2.1	2.5	2.9	3.3	3.7	4.1	4.5	4.9	5.8	6.6	8.2	10.3	12.4
	45	0.4	0.5	0.7	0.9	1.1	1.3	1.4	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.3	5.1	5.8	7.2	9.1	10.9
	60	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.7	2.0	2.3	2.7	3.0	3.4	3.7	4.0	4.7	5.4	6.7	8.4	10.1
	90	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	4.2	4.8	6.0	7.5	9.0
	150	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.4	1.7	2.0	2.3	2.6	2.9	3.2	3.4	4.0	4.6	5.7	7.2	8.6
24	24	0.4	0.6	0.8	1.0	1.2	1.5	1.7	2.1	2.5	2.9	3.3	3.7	4.1	4.5	5.0	5.8	6.7	8.2	10.3	12.4
	32	0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.2	2.6	2.9	3.3	3.6	4.0	4.3	5.1	5.8	7.2	9.0	11.0
	50	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.5	1.8	2.2	2.5	2.8	3.1	3.4	3.7	4.4	5.0	6.2	7.8	9.4
	70	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.0	3.3	3.8	4.4	5.5	6.9	8.2
	100	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.3	1.6	1.8	2.1	2.4	2.6	2.9	3.1	3.7	4.2	5.2	6.5	7.9
	160	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.8	3.3	3.8	4.7	5.9	7.1
30	30	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.7	5.4	6.7	8.4	10.0
	45	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.4	1.7	1.9	2.2	2.5	2.7	3.0	3.3	3.8	4.4	5.5	6.9	8.2
	60	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.5	1.7	2.0	2.2	2.5	2.7	3.0	3.5	4.0	5.0	6.2	7.4
	90	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.5	2.7	3.1	3.6	4.5	5.6	6.7
	150	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.8	3.2	4.0	5.0	5.9
	200	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.6	3.0	3.7	4.7	5.6
36	36	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.4	1.7	1.9	2.2	2.5	2.8	3.0	3.3	3.9	4.4	5.5	6.9	8.3
	50	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.7	1.9	2.1	2.5	2.6	2.9	3.3	3.8	4.8	5.9	7.2
	75	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.3	2.5	2.9	3.3	4.1	5.1	6.1
	100	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.6	3.0	3.8	4.7	5.7
	150	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.4	2.8	3.5	4.3	5.2
	200	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.3	1.5	1.6	1.8	2.0	2.3	2.6	3.3	4.1	4.9
42	42	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.6	1.9	2.1	2.4	2.6	2.8	3.3	3.8	4.7	5.9	7.1
	60	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.8	3.2	4.0	5.0	6.0
	90	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.4	2.8	3.5	4.4	5.2
	140	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.9	2.2	2.5	3.1	3.9	4.6
	200	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.7	2.0	2.3	2.9	3.6	4.3
	300	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.7	0.8	0.9	1.1	1.3	1.4	1.5	1.7	1.9	2.2	2.8	3.5	4.2

1. Cavity Depth = the distance (in feet) between the work-plane and the ceiling

Source: IES Handbook 1981 Reference Volume

Table 12. Lamp Replacement Guide

Existing Lamp Now Used	Recommended Replacement Lamp For Reduced Energy Consumption	Lamp Watts (1)	Life (Hours)	Replacement Lamp Description or Equivalent	Usual Application
FLUORESCENT LAMPS					
F15T8/WW or CW	None	15	7,500		Show Case Ltg
F15T12/WW	None	15	7,500		Show Case Ltg
F20T12/WW or CW	None	20	9,000		General Ltg (2)
F30T12/WW	F30T12/WW/RS/WM	25	18,000	Watt-Miser	General Ltg
F30T12/CW	F30T12/CW/RS/WM	25	18,000	Watt-Miser	General Ltg (2)
F40/WW	F40WW/RS/WM	35	20,000	Watt-Miser (3)	General Ltg
F40/CW	F30CW/RS/WM	35	20,000	Watt-Miser (3)	General Ltg (2)
F40/D	F40D/RS/WM	35	20,000	Watt-Miser (3)	General Ltg (2)
F40/WWX	F40WWX/RS/WM	35	20,000	Watt-Miser (3)	General Ltg (2)
F48T12/WW	None	40	9,000		General Ltg
F48T12/CW	F48T12/CW/WM (4)	35	9,000	Watt-Miser (3)	General Ltg
F96T12/WW	F96T12/WW/WM (4)	60	12,000	Watt-Miser (3)	General Ltg
F96T12/CW	F96T12/CW/WM (4)	60	12,000	Watt-Miser (3)	General Ltg (2)
F96T12/CWX	F96T12/CWX/WM (4)	60	12,000	Watt-Miser (3)	General Ltg (2)
F48T12/WW/HO or CW	None	60	12,000		General Ltg
F96T12/WW/HO	F96T12/WW/HO/WM (4)	95	12,000	Watt-Miser (3)	General Ltg
F96T12/CW/HO	F96T12/CW/HO/WM (4)	95	12,000	Watt-Miser (3)	General Ltg (2)
F48PG17/WW or CW	None	110	12,000		General Ltg
F96PG17/WW	F96PG17/WW/WM (4)	185	12,000	Watt-Miser	General Ltg
F96PG17/CW	F96PG17/CW/WM (4)	185	12,000	Watt-Miser	General Ltg (2)
F96PG17/CWX	None (1)(5)	215	12,000		
F96T12/CW/1500	F96T12/CW/1500/WM	185	12,000	Watt-Miser	
MERCURY LAMPS					
H175WDX39-22	None	175	24,000		General Ltg
H250WDX37-5	None (6)	250	24,000		General Ltg
H400WDX33-1	None (6)	400	24,000		General Ltg

Table 12. Lamp Replacement Guide - Continued

Existing Lamp Now Used	Recommended Replacement Lamp For Reduced Energy Consumption	Lamp Watts (1)	Life (Hours)	Replacement Lamp Description or Equivalent	Usual Application
INCANDESCENT LAMPS					
15A15 - 125/130	15A15 - 120	15	2,500	Extended Service-120V	Displays
25A - 125/130	25A - 120	25	2,500	Extended Service-120V	Displays
40A/99 - 125/130	25A - 120 (7)	25	2,500	Extended Service-120V	General Ltg
60A/99 - 125/130	40A/99 - 120 (7)	40	2,500	Extended Service-120V	General Ltg
75A/99 - 125/130	60A/99 - 120 (7)	60	2,500	Extended Service-120V	General Ltg
100A/99 - 126/130	75A/99 - 120 (7)	75	2,500	Extended Service-120V	General Ltg
150A23/99 - 125/130	100A/99 - 120 (7)	100	2,500	Extended Service-120V	General Ltg
200/99 - 125/130	150A23/99 - 120 (7)	150	2,500	Extended Service-120V	General Ltg
300M/99 - 125/130	200/99 - 120 (7)	200	2,500	Extended Service-120V	General Ltg
30R20	None	30	2,000		Displays
50R20	None	50	2,000		Pictures & Mirrors
75R30/SP or FL	75PAR/SP or FL	75	2,000	Par Projector	General/Accent
150R40/SP or FL	75PAR/SP or FL (7)	75	2,000	Par Projector	General/Accent
300R40/SP or FL	150PAR/SP or FL (7)	150	2,000	Par Projector	General/Accent
500R40/SP or FL	Q250PAR/SP or FL (7)(8)	250	6,000	Quartz Projector	Escalator Well
75PAR/SP or FL	None	75	2,000		General/Accent
150PAR/SP or FL	100PAR/SP or FL	100	2,000	Par Projector	General/Accent
150PAR/35P or 3FL	None	150	2,000		General/Accent
200PAR/3MFL	150PAR46/3MFL	150	2,000	Par Projector	General/Accent
200PAR/3NSP	150PAR46/3NSP	150	2,000	Par Projector	General/Accent
Q250PAR/SP or FL	150PAR/SP or FL	150	2,000	Par Projector	General/Accent

GENERAL NOTES:
(1) Lamp watts listed for fluorescent and mercury lamps do not include ballast loss.
(2) For general fluorescent lighting WW (warm white) is the generally preferred lamp color. CW (cool white) and WW (warm white) lamps should not be mixed in the same space.
(3) Do not use Watt-Miser // lamps unless the ballast is specifically designed for use with these lamps (GE ballasts only).
(4) Use only with ballast labeled for use with this lamp.
(5) Consider replacing with Watt-Miser Lamp of closest color.
(6) Consider use of dual wattage ballasts 250/195 and 400/300 watts.
(7) Replacement is made at almost no reduction in light output; lamp life of extended service lamps will be reduced to 2,500 hours.
(8) Required mogul to medium socket reducer.

Table 13. Luminous Efficacy

Light Source	Lumens per Watt
Low pressure sodium	183
Natural light	120 (varies)
High pressure (HD) sodium	105-120
Metal halide	85-100
Fluorescent	67-91
Mercury vapor	56-63
Incandescent	17-22

PROFESSIONAL CONTACT LIST

Note: A list is currently being compiled to provide NCEL and other Navy professional contacts for each ECO and ES option included in A-LESP.

This professional contact list will be forwarded as a change package at the earliest available date.

Current NCEL contacts:

-Facilities Engineering Support Office (FESO)
Pete Tafoya, NCEL Code L03C, A/V 360-4070
FTS 799-4070
(805)982-4070

(Liaison between field activities and NCEL technical staff in response to field inquiries/problems.)

-A-LESP Project Engineer
Doug Dahle, NCEL Code L73, A/V 360-4675
FTS 799-4675
(805)982-4675

FORM I

REPRESENTATIVE FACILITIES AND CORRESPONDING ENERGY OPTIONS

Representative Facility/System (i.e., Bldg No.)	Type of Facility (i.e., Hangar)	Possible ECOs (Section-Option)	Possible ESs (Section-Option)	Extrapolation Factor

Page ____ of ____

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REPRESENTATIVE FACILITIES AND CORRESPONDING ENERGY OPTIONS

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FORM II

PLANNING PROCEDURE SUMMARY

1 NO.	2 ECO/ES OPTION	3 REPRE-SENTATIVE FACILITY	4 NATIONAL ENERGY SAVINGS (NES) (MBtu/yr)	5 LIFETIME OPERATION SAVINGS (S)($)	6 LIFETIME INVESTMENT (I)($)	7 EXTRAP FACTOR	8 TOTAL NATIONAL SAVINGS (MBtu/yr)	9 TOTAL INVESTMENT ($)	10 SAVINGS INVEST RATIO (SIR) (S/I)	11 FUNDING CATEGORY	12 ENERGY GOAL CATEGORY
						PAGE TOTAL					
						CUMULATIVE TOTAL					

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PLANNING PROCEDURE SUMMARY

1 NO.	2 ECO/ES OPTION	3 REPRE-SENTATIVE FACILITY	4 NATIONAL ENERGY SAVINGS (NES) (MBtu/yr)	5 LIFETIME OPERATION SAVINGS (S)($)	6 LIFETIME INVESTMENT (I)($)	7 EXTRAP FACTOR	8 TOTAL NATIONAL SAVINGS (MBtu/yr)	9 TOTAL INVESTMENT ($)	10 SAVINGS INVEST RATIO (SIR) (S/I)	11 FUNDING CATEGORY	12 ENERGY GOAL CATEGORY
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FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ______
		ACT. FACILITIES ______
		______
		OPTION SHEET NO. ______
		A-LESP SURVEY DATE ______
		OPT. FEASIBILITY (YES/NO) ______
		NES ______
		SIR ______
		FOLLOW-ON SURVEY DATE ______
		PROJECT SUBMITTAL DATE ______
		PROJECT COMPLETION DATE ______

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ______
		ACT. FACILITIES ______
		______
		OPTION SHEET NO. ______
		A-LESP SURVEY DATE ______
		OPT. FEASIBILITY (YES/NO) ______
		NES ______
		SIR ______
		FOLLOW-ON SURVEY DATE ______
		PROJECT SUBMITTAL DATE ______
		PROJECT COMPLETION DATE ______

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE

REP. FACILITY ____________________

ACT. FACILITIES ____________________

____

OPTION SHEET NO. ____________________

A-LESP SURVEY DATE ____________________

OPT. FEASIBILITY (YES/NO) __________

NES ____________________

SIR ____________________

FOLLOW-ON SURVEY DATE __________

PROJECT SUBMITTAL DATE __________

PROJECT COMPLETION DATE __________

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ____________
		ACT. FACILITIES ____________
		____________
		OPTION SHEET NO. ____________
		A-LESP SURVEY DATE ____________
		OPT. FEASIBILITY (YES/NO) ____________
		NES ____________
		SIR ____________
		FOLLOW-ON SURVEY DATE ____________
		PROJECT SUBMITTAL DATE ____________
		PROJECT COMPLETION DATE ____________

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ____________________
		ACT. FACILITIES ____________________
		____________________
		OPTION SHEET NO. ____________________
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		OPT. FEASIBILITY (YES/NO) ____________
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		PROJECT SUBMITTAL DATE ____________
		PROJECT COMPLETION DATE ____________

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ____________
		ACT. FACILITIES ____________
		____________
		OPTION SHEET NO. ____________
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		NES ____________
		SIR ____________
		FOLLOW-ON SURVEY DATE ____________
		PROJECT SUBMITTAL DATE ____________
		PROJECT COMPLETION DATE ____________

CALCULATIONS	*DATA VALUE USED*

FORM III

OPTION CALCULATION SHEET

<u>ASSUMED SURVEY DATA</u>   <u>VALUE</u>

REP. FACILITY ____________________
ACT. FACILITIES ________ ________
____
OPTION SHEET NO. ____________________
A-LESP SURVEY DATE ____________________
OPT. FEASIBILITY (YES/NO) __________
NES ____________________
SIR ____________________
FOLLOW-ON SURVEY DATE __________
PROJECT SUBMITTAL DATE __________
PROJECT COMPLETION DATE __________

<u>CALCULATIONS</u>   <u>DATA VALUE USED</u>

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA	VALUE	
		REP. FACILITY ________________
		ACT. FACILITIES ________________
		________________
		OPTION SHEET NO. ________________
		A-LESP SURVEY DATE ________________
		OPT. FEASIBILITY (YES/NO) ________
		NES ________________
		SIR ________________
		FOLLOW-ON SURVEY DATE ________________
		PROJECT SUBMITTAL DATE ________________
		PROJECT COMPLETION DATE ________________

CALCULATIONS	DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA | VALUE

REP. FACILITY ______________________
ACT. FACILITIES ____________________
____
OPTION SHEET NO. ___________________
A-LESP SURVEY DATE _________________
OPT. FEASIBILITY (YES/NO) __________
NES ________________________________
SIR ________________________________
FOLLOW-ON SURVEY DATE ______________
PROJECT SUBMITTAL DATE _____________
PROJECT COMPLETION DATE ____________

CALCULATIONS | DATA VALUE USED

FORM III

OPTION CALCULATION SHEET

ASSUMED SURVEY DATA | VALUE

REP. FACILITY ______________________

ACT. FACILITIES ____________________

____

OPTION SHEET NO. ___________________

A-LESP SURVEY DATE _________________

OPT. FEASIBILITY (YES/NO) __________

NES ________________________________

SIR ________________________________

FOLLOW-ON SURVEY DATE ______________

PROJECT SUBMITTAL DATE _____________

PROJECT COMPLETION DATE ____________

CALCULATIONS | DATA VALUE USED

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